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I.

Clavis Cæleſtis.

BEING THE

EXPLICATION

OF A

DIAGRAM,

ENTITULED A

Synopſis of the UNIVERSE:

OR, THE

Viſible WORLD

EPITOMIZED.

> *Sed nihil in totæ magis eſt mirabile Mole,*
> *Quam Ratio, & certis quod Legibus omnia parent.*
> MANIL. L. I. Aſtron.

By *THOMAS WRIGHT*, late of the City of *Durham*.

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1742

T. WALKER

Tailor,

DARLINGTON.

31 MAY 81

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THE
Viſible CREATION
EPITOMIZED,

Comprehending in general, at one View,

THE

PHYSICAL and MATHEMATICAL

ELEMENTS of ASTRONOMY,

Both antient and modern:

Illuſtrated with many original, demonſtrating SCHEMES, the lateſt Teleſcope Diſcoveries, and ſeveral entire new TABLES never before publiſh'd.

THE

SUMMARY.

IN the following Sheets, are contained a regular and compleat Courſe of ſpeculative Aſtronomy, repreſenting and explaining the ſeveral known Laws and Principles of the planetary Syſtem; and the various Hypotheſes, and Opinions of the moſt eminent Authors, relating to the viſible Creation: demonſtrating the Motions, Magnitude, and mutual Diſtances of the heavenly Bodies in all Poſitions, their Eclipſes, Tranſits and Occultations, Light, Heat, Nature and phænomenal Viciſſitude, *&c.*

T. W.

St *James's*,
Jan. 1735.

PREFACE.

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PREFACE.

THE Mind of Man being ever thirſty after Knowledge, reſtleſs in its Purſuits, and fond of Diſcoveries, eaſily catches at every Object that preſents itſelf to View; but holds to that alone, which, being well weigh'd and examined, ſeems to have gain'd the Advantage of Truth; from whence, like a fair City on a high Hill, it commands Attention and Reſpect, from the preſent and ſucceeding Ages.

This every Syſtem may be properly ſaid to have done, when either thro' its own Reaſonableneſs, it has been univerſally (at leaſt by thoſe who are competent Judges) aſſented to without any Contradiction; or when, thro' the Fame of the Author, the Uſefulneſs or Entertainment of the Theory, it has withſtood the Attacks of Envy, and inſinuated itſelf into the good Eſteem of the World.

The firſt is the beſt Teſtimony; for by the latter we may be led, thro' Prevalency, to give our Aſſent to known Falſhoods, or at beſt, groſs Abſurdities; Fiction not being without its Partizans, and but too often triumphs over Truth itſelf, eſpecially if dreſs'd in the pleaſing Garb of Wit; and 'tis equal to us, whether thro' Deſign of the Relater, to impoſe on, or Heedleſſneſs, in ſuffering himſelf to be deceived by the World, we are led into *Error*; the Conſequences being alike fatal, and the Miſchief, when once taken Root, hard, if ever, to be weeded out.

The AUTHOR of the following Sheets, hopes he ſhall avoid both theſe Imputations, having us'd his utmoſt Diligence to become a Maſter of the Subject whereon he treats, and taken that for his Foundation, which has now, for a long Period of Time, been almoſt without Exception agreed to.

As to the Uſefulneſs of the Subject, he hopes the Authority of thoſe many great and learned Men, who, in all Ages, have thought it well worth their while to beſtow their Time and Pains therein, will be a ſufficient Excuſe: Whether he has been happy enough to ſucceed in his Deſign of putting that, which has been already treated of by others, in a clearer and plainer Light, and opening a wider Gate to this fair Field of Knowledge, by adding ſome few Poſitions of his own, muſt be left to the Deciſion of the *Publick:* However, this he takes for granted, the Path, he has here chalk'd out, is at leaſt new, and if any greater Genius may be incited by this, to go a further Progreſs in this Science, he will not think his Labour loſt.

And certainly, if *Hiſtory* is reckoned one of the moſt advantageous Studies, for that it leads the Mind forth, as it were among the buſy Sons of Men without Fatigue, calls back paſt Ages, and makes it acquainted with different Nations, without the Expence or Hazard of Travelling, well may this *Treatiſe* claim ſome Reſpect: It diſcloſing, not the Laws of *particular* Parts of this World only, but making an Excurſion even into *Infinity*, (if the Expreſſion may be allow'd) diſcovering the Principles of Nature, and ſhewing the Certainty of her Ways, under the Government of an All-wiſe, Eternal, and Omnipotent Being.

Some well-meaning Perſons may imagine, this is taking a Step too far, and laying Claim to what we can have no Right; but ſurely if we may have Leave to ſuppoſe, the Intent and Deſign of the great Creator, in theſe ſtupenduous Works, was to receive Praiſe and Honour, as far as we poor Mortals are capable of underſtanding them, (which God knows is in a very ſmall Degree) then nothing done with *that* View can be too much.

'Tis poſſible at firſt View, a Treatiſe on the *Syſtem* of the Planets alone, may not ſeem, in any great Degree, to aſſert or vindicate the Idea of Omnipotence; but 'tis as poſſible, on a nearer Conſideration, that by moſt of our Readers it will be readily granted, that nothing under *infinite Power* and infinite Wiſdom, could firſt *make*, and afterwards *ſuſtain* the prodigious Fabrick of the WORLD and the VISIBLE CREATION, taking no more of it into Conſideration, than what is obvious to our Senſes: But if we ſuffer our Minds to range in the vaſt Expanſe, as far as Contemplation (and that on a bare Parity of reaſoning) will carry us, we muſt be loſt in Amazement, and can have no room to doubt, either the Wiſdom or Power of that Being, who created and governs it.

And what Study, more peculiarly adapted to raiſe Contemplations of that Kind in the Mind, than conſidering the Earth on which we live, and the Heavens with which we are ſurrounded? And if (as we ought) we regard ourſelves as nothing, when we look at the immenſe Diſtance between us and Perfection; yet, how high above that Idea may we not juſtly raiſe ourſelves, if we reflect on the Myriads of minute Beings animate and inanimate below us? 'Tis our peculiar Privilege to be plac'd (as it were) in the Center of Life; the conjoining Mean of the two greateſt Extreams, *a Deity* and *Duſt*; and by the Mixture of both Natures, enabled to partake of every Good, produced by either, from the loweſt Pleaſure of *Senſe*, up to the higheſt Raptures of *Immortality*.

The Work itſelf has ſeveral Things to recommend it beſides Uſefulneſs; in particular, the ſeldom failing Plea of Novelty, and that both as to Matter and Manner; not only great Part of the Subject, being quite new (in a Tract of this Kind) but alſo the Method of treating it, *viz.* clearly and plainly. Here are no dry and tedious Deſcriptions of Things, quite foreign to the Purpoſe; nor any far-fetch'd, uſeleſs Definitions, to affright or puzzle the ignorant, or affront the learned Reader: And where it would allow of it, Schemes are reduced, not only to occular but mathematical Demonſtration. The Author therefore hopes he hath attain'd the Points he aim'd at in this Publication, which were on one Hand, to inſtruct thoſe who know nothing of this delightful Science; and on the other, not to be quite uſeleſs to thoſe who may have ſpent ſome Time and Pains in this Branch of Knowledge, by offering ſomething to their Conſideration, which has not been taken Notice of by any of the Authors who have already wrote on this Subject; if he ſhould be miſtaken in his Conjectures (as who alive is free from Error?) he hopes the Goodneſs of his Deſign, will in ſome Meaſure plead his Excuſe, if not wholly obtain his Pardon.

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THE

INTRODUCTION.

ASTRONOMY, deriv'd from Αςηρ a Star and Νομος a Law, teaches us the firſt Order and Laws of the material World; and is a Science, by which the whole Frame of Nature is made adequate to our Faculties, and rendered intelligible to the human Mind. It is by this, the moſt uſeful of all natural Knowledge, the Deity himſelf is made manifeſt to Mortals, in the moſt ſuperlative Degree of his infinite Attributes; wherein his divine Being, Supremacy, and Super-intendency, are not only exhibited to our Senſes, but abſolutely prov'd by infallible Reaſoning, and made evident to a Demonſtration.

By theſe ſublime Speculations alone, we are enabled to comprehend, the almoſt infinite, extent of the VISIBLE

Creation, and with the Eye of Reaſon and Analogy, penetrate ſtill farther, where real Demonſtration fails; ſolving the vaſt indefinite Proſpect of the Univerſe, and the glorious Phænomena of its conſtituent Parts.

In Contemplation of which ſtupenduous Frame, we are naturally led into the pleaſing Reflection of finding ourſelves under the ſame providential Care and Government. with the infinite Whole, and our Faith eſtabliſhed in the great Creator; who, by all Marks of Majeſty and Dominion, has form'd us in the only Mould, which imitates himſelf, and made us to be the the only Rational of all known Beings, declaring us by this Act alone, his moſt peculiar Favourites.

This then, the nobleſt of all Sciences, which in itſelf comprehends the very Foundation of all others, juſtly claims the Pre-eminence due to it, as the primitive Study of Mankind; and ought to be regarded as the only Means by which we can poſſibly arrive at any tolerable Knowledge of our own State; and the Minuteneſs of our preſent Being, compared with what we may hereafter reaſonably expect, and that our future Hopes may promiſe us in a Life to come.

But leaſt I ſhould be taxed with Partiality to this, as my favourite Study, and be judg'd to drive the Knowledge of the Deity, (who is undoubtedly Omnipreſent) from my own more immediate Habitation, and out of all other Arts and

Sciences, wherein he is as undeniably viſible, his Wiſdom and Power as much unlimited, and not at all leſs to be glorified, I ſhall content myſelf with what is already ſaid upon it, and proceed to give ſome little Account of its Antiquity and Progreſs.

Aſtronomy, as far as we can trace it backwards, looking into paſt Time, and towards its Fountain Head, we find chiefly owes its original to the antient *Arabians*, or as ſome ſay, to the *Chaldean Shepherds*; who having, from the Nature of their Employment, much more Time upon their Hands than the Reſt of Mankind, ſeem to have made it their early Study, or rather their Amuſement, whilſt their Flocks were feeding upon the Mountains.

The firſt we read of, who more ſtrictly apply'd themſelves to this Study were the *Sons of Seth*, who, as *Joſephus* relates, very early obſerv'd the Order of the Heavens and Courſe of the Stars; and we are told by the ſame Author, that *Adam* having predicted a twofold Deſtruction of the Earth, one by Water, and the other by Fire; leaſt their Inventions and Diſcoveries ſhould ſlip out of the Remembrance of the remaining Part of Mankind, they erected two Columns, one of Stone and the other of Brick, and inſcribed their choiceſt Inventions upon both of them; that in Caſe the Brick one ſhould be deſtroy'd by a Deluge, that of Stone might remain; or otherwiſe, if the Stone one ſhould be demoliſhed by a Conflagration, that of Brick might remain, and by this Means afford Poſterity an Opportunity of being inſtructed in the Knowledge they had gain'd.

It is alſo reported of *Seth* or *Seſoſtris*, King of *Egypt*, that two ſuch Pillars were raiſed by him, and upon a like Occaſion, in the Land of *Siriad*; one of which being of Stone, preſenting to view a like Dedication to Poſterity, if Hiſtory ſay true, is yet to be ſeen, even in our Days. Mr *Whiſton* relates from *Joſephus* and others, of the moſt antient Hiſtorians in his Account, of the Riſe and Progreſs of the Mathematicks, that the *Aſſyrians* and *Chaldeans* were the firſt after the Flood, who applied themſelves to the mathematick Arts; which as he ſays, firſt ſprung up and flouriſh'd amongſt the latter, and was afterwards transfer'd to the *Egyptians* by * *Abraham*.

From *Egypt* this Science croſs'd the Seas to *Greece*, from *Greece* was tranſmitted to *Rome*, and from thence, by the Extent of the *Roman* Conqueſts at length to *Albion*, now call'd *England*, where we at preſent enjoy it in its utmoſt Perfection, being able to determine by unerring Rules, the true Place, Poſition, *&c.* in the Heavens, of every known Star, Planet or Comet, to any Time, paſt, preſent or to come.

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* *Abraham* ſeeing the *Egyptians* take delight in Arts and Sciences, is ſaid to have communicated Geometry and Aſtronomy to them, upon his firſt Arrival in *Egypt* out of *Paleſtine*; others will have the Mathematick Arts to be firſt found out by the *Egyptian* Prieſts themſelves.

It has been ſaid already, that the antient Shepherds were ſuppoſed to be the firſt Aſtronomers upon the Earth, and that the *Egyptians* were the earlieſt Improvers of it, being originally taught by *Abraham*, who, as we are told by the primitive Hiſtorians, communicated to them the firſt Scheme of the Heavens, as an Hypotheſis produced by the *Chaldeans* to ſolve the diurnal and annual Appearances of the Sun, Moon and Stars; and in particular, five very remarkable Bodies, like Stars, which Length of Time and conſtant Obſervation had render'd notable. Theſe Bodies, tho' in general much brighter than the reſt of the Stars, were obſerved to have very little or no * Senſtillation, and in particular to ſhine much brighter at one Time than at another; ever increaſing or decreaſing their Luſtre, and to be very irregular in their Motions, always changing their Poſition to the Eye, and never to be found in the ſame Situation amongſt the fix'd Stars.

The *Chaldean* Syſtem therefore, in order to account for theſe Appearances, imagines the WORLD or VISIBLE CREATION to be moveable in the following Manner, *viz.*

Firſt, in the Center of the Univerſe is imagin'd the Earth, and next above the elementary Regions, the Moon; then the two leaſt wandering of the five erratic Stars, which were always obſerved to be in the Neighbourhood of the Sun; next above them the Sun himſelf, and then again above him

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* Twinkling occaſioned by an Undulation of the Particles of Air in our Atmoſphere.

the other three, which were the moſt irregular of all. Theſe five itinerant Bodies, together with the Sun and Moon, were by the Antients call'd Planets, and from what follows, 'tis plain the old Heathen Worſhip took Place in the World long before the Science of Aſtronomy came to any Maturity.

Since, from the firſt Beginning we find it dignified with the Names of their ſupream Gods, the Chief of which, being *Saturn*, *Jupiter*, *Mars*, *Venus*, *Mercury*, *&c.* and it is not unlikely that the firſt planetary Syſtem may have been form'd ſome time before the dethroning of *Saturn*, by his Son *Jupiter*, by reaſon we find the higheſt Planet in the Syſtem, and conſequently the Chief in Point of Place is call'd *Saturn*, (in *Greek* Κρονος or Φαινων) after his Name; the next inferior to him is call'd *Jupiter*, in *Greek* Ζευς and Φαεθων, and next to *Jupiter* is *Mars*, call'd in *Greek* Αρης and Πυρεις, and by ſome aſtronomical Writers, the Star of *Hercules*.*

Thus far both the ancient and modern Aſtronomers, all agree, in reſpect of the Order of theſe three Planets, which we

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* *Zoroaſter* the ancient and great *Chaldean* Philoſopher, conſecrated a natural Cave, ſacred to *Mithra* (or the Mind) ſome ſay, in the *Perſian* Mountains, in which the ſeven Planets were repreſented by ſeven Gates, one riſing ſeveral Steps above another, upon a Flight of Stairs.

The 1ſt was Lead, as an Emblem of	*Saturn.*
2d Tin,	*Venus.*
3d Braſs,	*Jupiter.*
4th Iron,	*Mercury.*
5th Leather,	*Mars.*
6th Silver,	*Moon.*
And the 7th was Gold, to repreſent the *Sun*, or	*Mithra.*

we call Superior, but with this material Difference, in regard to their Motions, namely, the former imagine them to move round the Earth as their common Center, and the latter round the Sun.

The ſecond Syſtem we read of, is that mentioned by *Vitruvius* in his Book of Architecture, and approved of by *Argol*, *Macrobius*, and venerable *Bede*, in his Book of the Nature of Things, invented, or rather improv'd, as it is ſuppoſed by the Magi or Magicians of *Egypt*, who are alſo ſuppoſed to have firſt invented the ſeven Characters, to expreſs the Planets in their Hieroglyphicks.

In this, the firſt Planet is *Luna*, (Σελήνη) or the Moon repreſented moving round the Earth, and next to her the Sun (in *Greek* call'd Ἥλιος) then round the Sun as the common Center of their Motions are the Orbits of the two inferior Planets, mentioned before as being always in the Neighbourhood of the Sun: Firſt *Mercury*, called in *Greek* Ἑρμῆς and Στιλβων, and by ſome the Star of *Appollo*, and then *Venus*, or Αφροδιτη called ſometimes the Star of *Juno*; by ſome *Iris*, and by others the Mother of the Gods. The firſt of theſe Planets is never to be found diſtant from the Sun $\frac{1}{12}$ part of the Heavens, nor the latter, more than one Octant, which plainly proves their Motions to be round the Sun, and here truly repreſented. As a Conſequence of which we ſee them both through Telleſcopes, horn'd, gibboſe and full, and to have all the Phaſes of our Moon.

Thus far the Conjectures of the Ancients prove to be true, the reſt of the Planets, *viz. Saturn, Jupiter,* and *Mars,* as in their aforementioned Order, they ſuppoſed to move at a vaſt Diſtance without the Sun's Orbit, and round the Earth as their common Center.

This Syſtem long lay dormant amongſt the old *Egyptian* Rowls, but at length Time and Opportunity again renewed it, and in the *Philolaic* Schools of *Greece,* received ſuch great Improvements as to gain the Eſteem of all the *Greek* Philoſophers, in particular *Pythagoras* and his Followers. Being ſtill more and more confirmed by Obſervations to the Time of *Ariſtarchus,* and now in great Meaſure proved, all the Planets were imagined to move round one common Center, the Sun; which they ſuppoſed to be the only Fountain of Light, Heat, and Gravity in the Syſtem, where as before *Saturn, Jupiter, Mars,* and the Sun himſelf had been conjectured to revolve round the Earth. *

In this Syſtem the Planets are in the following Order:

1ſt, in the Center the *Sun.*
2dly, round him *Mercury.*
3dly, the Orbit of *Venus.*

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* It is reported of one of the *Ptolomies* of *Egypt,* that ſoon after theſe Diſcoveries, he erected a Temple ſacred to the Sun, and as a Symbol of the Univerſe, placed in it all the Planets in their proper Orbits round him; the Sun himſelf being repreſented by a conſtant Fire, in the Middle of it.

4thly, that of the *Earth*, { and about the *Earth* the *Moon*.
5thly, the Orbit of *Mars*.
6thly, that of *Jupiter*.
And laſtly, that of *Saturn*, { Without which at a great Diſtance they placed the Sphere of fix'd Stars.

This Syſtem had not long been received before the *Pythagorian* Philoſophy began to decline, and that of the *Platonicks* to take Place, about which Time *Plato* produced another Syſtem, but as much different from the former, as if Aſtronomy had never been, or at leaſt all Pre-knowledge for ſome time quite loſt.

In this the Earth was again made to re-aſſume the Center; next the Earth he placed the Element of Air, and upon the Convexity of this the Element of Fire, above theſe he fixed the Sphere of the Moon, and without that the Region of the Sun, next *Mercury*, then *Venus*, without which *Mars*, above him *Jupiter*, round all *Saturn*, and laſtly, the Orbit of fixed Stars; all moving in various Periods round the Earth.

How this Syſtem was received in the World we have no Account farther, than that we read of *Porphyrius* about 750 Years after, not approving of the Orbit of *Mercury* changed that of *Venus* into its Place ſuppoſing all the reſt as *Plato* had ſuggeſted.

Soon after the Age of *Chriſt* about the Year 140 Aſtronomy began to revive again, under the Inſpection of *Claudius Ptolomeus*, born at *Peluſiam* a City in *Egypt*. This Prince of Aſtronomers, but much more famous for his *Catalogue of Stars*, than his *Syſtem of Planets*, diſapproving of what *Plato* and the reſt had writ before him, invented another Hypotheſis, but not much different from the former, chiefly varying in the Place of the Sun; which in this you'll find in the fourth Orbit, whereas in that of *Plato*'s 'tis in the ſecond. In this the Earth ſtill keeps her Place in the Center of the Univerſe immoveable, and round the Earth all the planetary Motions are ſuppoſed to be perform'd in ſolid Orbits from Weſt towards Eaſt. Without the Orbit of *Saturn*, upon the Convexity of each other, this Author imagined three principal Spheres, (*viz.*) 1ſt, that of the fix'd Stars, 2dly, one called the Chryſtaline Heaven, and laſtly, another called the Primum Mobile. The fix'd Stars he look'd upon to be no other than Loop-Holes of various Sizes through which appeared, as he thought, the Light of the Chryſtaline Heaven; and to the Primum Mobile he attributed the Viciſſitude of Night and Day, which he ſuppoſed to make one Revolution round the Poles of the World from Eaſt to Weſt, (ſolving the diurnal Motion of the Stars) in 24 Hours. This Syſtem was ſoon found much more ingenious than true, and is now quite exploded.

In the fourteenth Century, after *Ptolemy*'s * Time, about the Year 1500, *Nicolaus Copernicus*, a Native of *Thorn* in *Poliſh Pruſſia*, began again to introduce the old *Philolaic* Syſtem, as before deſcribed, which till then had lain unknown, or at leaſt unimbraced almoſt 2000 Years, and upon the Revival of which, Aſtronomy now began to flouriſh in *Europe*; but many Objections were made to this new Aſtronomy by the Philoſophers of his Time, upon Account of the Earth's being made to move out of its Place and round the Sun in a Year, and at the ſame Time round its own Axis in a Day. Theſe two great and chief Difficulties, tho' one of them ſolv'd the Seaſons, and the other the Viciſſitude of Day and Night, both in the moſt natural Manner, they could by no Means reconcile; at length the great *Tycho Brahe* took this Hypotheſis into Conſideration, and made the following Alterations in it.

The Earth, he imagined, to be fixed and immoveable in the Center of the Sphere of the fixed Stars, and conſequently to theſe he was obliged to give a diurnal Motion altogether round the Poles of the Heavens; the Orbits of the Sun and Moon, he made concentric to the Earth, and moving round the former, agreeing ſo far with *Copernicus*, he allowed all the five erratick Stars to move, and in the ſame Order as *Copernicus* had placed them. But this Syſtem

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* A notable Inſtance of the ſlight Progreſs of this Study in ſo many Years.

did not anſwer the general Satisfaction; ſo thoſe who could not digeſt it (and ſome will have it himſelf alſo in his latter Days) to remedy the chief Abſurdity, which was no leſs than that of the real Motion of the whole Heavens, round the Earth in 24 Hours, gave the Earth a daily Motion round her Axis. This little Rotation of the Earth round itſelf, which is performed from Weſt to Eaſt, is of ſo great Conquence as to ſave the Sun, Moon, and all the Stars the Trouble and Difficulty of moving altogether in their regular Order round the Circumferences of Heaven, and which they nevertheleſs appear to do from Eaſt to Weſt in the ſame Space of Time.

This Syſtem is called the *Semi-Tychonic*, from retaining only Half of *Tycho*'s Conjectures, all the other Parts agreeing with *Copernicus*, and many of our modern Aſtronomers will hardly be perſuaded from giving this the Preference of all others, ſince, as they ſay, the Celeſtial Phenomena are entirely ſolv'd by it: But to this we may anſwer, 'tis evident that *Mars* and *Venus* actually move round the Sun, and the Earth we can abſolutely prove to be betwixt them (I mean their Orbits); hence it is manifeſt, if the two Extremes be allowed to move, the Mean muſt alſo. *Venus* we can alſo demonſtrate to be nearly of the ſame Magnitude and of a like Nature with the Earth, conſequently ought alſo to move in the ſame Manner, and be ſubject to the ſame Laws. But the moſt undeniable Reaſon for the Earth's Mo-

Motion, if we may credit Sir *Iſaac Newton*, is the annual Parallax of Comets. (*See his* Principia, *Book* 3. *Prop.* 42.) *

Ricciolus, a Native of *Italy*, having no good Opinion of either of the *Tychonic* or *Ptolemaic* Schemes, about the Year of CHRIST 1650, revived the antient *Egyptian* Syſtem, and adding *Mars* to the Attendance of the Sun, call'd the Whole his own.

This Syſtem was made to ſolve the Phenomena in many Caſes, but could never rightly account for the Motion of *Mars*; he was a much greater Philoſopher than an Aſtronomer, and I do not find that his Syſtem met with Encouragement.

All theſe various Syſtems here mentioned, you will find juſtly repreſented in the large Center Scheme, their Periods, Diſtances, and various Epicycles, *&c.* being of no manner of Signification now, I have thought it quite unneceſſary to take notice of them in this general Account, but ſhall be very particular, even in the moſt minute Circumſtances, when I come to treat of the true receiv'd Syſtem of the World; and, firſt, it will be neceſſary to explain ſome few aſtronomical Terms.

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* *Milton* ſeems to have been convinced of the Earth's Motion round the Sun, tho' in his Time this Syſtem was but very little known, by his puting the following Queries to *Adam* where *Raphael* ſays,

> - - - - - - - - - What if the Sun
> Be Center to the World, and other Stars,
> By his attractive Virtue and their own
> Incited, dance about him various Rounds?
> Their wand'ring Courſe, now high, now low, then hid,
> Progreſſive, retrograde, or ſtanding ſtill,
> In ſix thou ſeeſt, and what if, ſeventh to theſe,
> The Planet Earth, ſo ſtedfaſt though ſhe ſeem,
> Inſenſibly three different Motions move?

THE Way the Sun apparently deſcribes among the Stars, is call'd the * *Ecliptic* (becauſe in it, or near it, the Eclipſes of the Sun and Moon are made) to all Parts of this great Circle in the Heavens, if we ſuppoſe Lines or Radii directed from the Earth's Center, and continued *ad infinitum*, we may eaſily conceive an infinite Plain, in which the Earth is continually moving round the Sun, and conſequently out of this Line the Sun can never ſtray. But the Planets which all move round him, in different Plains, are all ſubject to an Appearance, more or leſs, on both Sides of it, according to the Inclination or Obliquity of their ſeveral Orbits with it, and their Diſtance from the Point of Interſection call'd their *Nodes*: And in order to take in the apparent Motion of the moſt wandering of them, there are two leſſer Circles ſuppoſed as Limits, to paſs parallel to each other, one on either Side diſtant from the Ecliptic nine or ten Degrees.

This *Zone* or *Belt* is call'd the *Zodiac*, and twelve of the Conſtellations that lie in or near that Way, are call'd Signs of the *Zodiac*, or of the *Solar Way*.

---

* The Ecliptic is ſaid to be firſt diſcovered as a great Circle by *Thales*, the *Mileſian*, about 584 Years before Chriſt, he was the firſt Obſerver of the Equinoxes and Solſtices, and is reported to have foretold an Eclipſe of the Moon to *Cyrus*.

Their, Order, Names, and Characters, as marked upon all Globes and Spheres, are as follows.

Names of the Signs, &c.

1	*Aries,*	♈	7	*Libra,*	♎
2	*Taurus*	♉	8	*Scorpio,*	♏
3	*Gemini,*	♊	9	*Saggittarius,*	♐
4	*Cancer,*	♋	10	*Capricornus,*	♑
5	*Leo,*	♌	11	*Aquarius,*	♒
6	*Virgo,*	♍	12	*Piſces,*	♓

Now every Circle is ſuppoſed to be divided into 360 Parts, call'd * Degrees, hence every Sign, being a $\frac{1}{12}$ Part of the Circumference, is 30 Degrees; and for the Uſes of Aſtronomy, Geography, *&c.* where great Exactneſs is required, every Degree is divided into 60 Parts call'd Minutes, and again, every Minute is ſubdivided into 60 Seconds.

Terms explained.

Anomaly, is the Quantity of Motion included betwixt the Place of a Planet in its Orbit, and the Point wherein it approaches neareſt the Sun.

---

* A Degree upon the Earth's Surface is 60 geographical Miles, but a Degree as far from the Earth as the Moon's Orbit, is 360 ſuch Miles, and their Quantities are always encreaſed or diminiſhed in Proportion to the Diſtance from the Eye, Sector Point, or Radius of the Circle.

Aphelion, that Point in any Planet's Orbit, moſt remote from the Sun; near this the Planets move ſhorteſt.

Apogeon, that Point where any Planet is fartheſt from the Earth; in this the heavenly Bodies appear the leaſt.

Excentricity, is in every Ellipſis, and is the Diſtance from either of the radial Points (otherwiſe call'd Focuſes) to the Center of the inſcribed Circle. In one of theſe Foci in every Planet's Orbit, the Sun in our Hypotheſis, is ſuppoſed to be placed.

Elongation, is the apparent Angle or Diſtance of any ſecondary Planet from its primary, view'd *extra Orbis,* or as *Venus* and *Mercury* are ſeen from the Earth with reſpect to the Sun.

Geocentric, Place or *Motion,* is with regard to the Appearance of any Object from the Earth.

Heliocentric, Place or *Motion,* is with reſpect to any Planet as it would appear from the Sun.

Inclination, is the Angle of Obliquity of any Planet's Orbit with that of the Earth's, or Plane of the Ecliptic.

Perigeon, is that Point in the Orbit of any Planet where it is neareſt to the Earth; here the Planet's Disk appears the largeſt.

Perihelion, is that Point or Part of any Planet's Orbit where the revolving Body approaches neareſt the Sun; in this the heavenly Bodies move faſteſt.

Parallax, is the Difference betwixt the true and apparent Place of any particular Phenomenon, and the horizontal Parallax is always the greateſt.

Parallax more fully explained.

This Diverſity of Appearances ariſing from the Change of Place, with regard to an Eye placed upon the Earth may be of many Kinds, both with reſpect to different Poſition in the Earth's Orbit, and alſo to the Situation of the Obſerver upon the Orb itſelf.

See the F I G U R E O.

The firſt and chief Cauſe of Parallaxes proceeds from the Magnitude of the Earth's Globe, or rather the Diſtance I A betwixt the ſenſible Horizon I D, and the rational Horizon A H; but the Quantity principally depends upon the Diſtance of the Object from the Eye, and then conſequently proportionally to the Diſtance of the Body from the Zenith.

Let B and C reſpectively repreſent the Sun and Moon in the ſenſible Horizon, which to an Obſerver at I will appear concentrically at D, but at the ſame Time to an Eye at the Earth's Center A, the Moon will appear to be at F, and the Sun at E: Thus the Angle I C A and I B A are reſpectively the horizontal Parallaxes of thoſe two Luminaries. And this being once known, the Radius of the Earth being always given, each reſpective Diſtance from the Earth may be eaſily found. (*Vide Solution of the Triangles.*)

G repreſents a Planet, whoſe Parallax is the Angle G I A, its true Place being at H, and its apparent Place at K. Hence by comparing the Angles at F, K and P aſcending to the Zenith, 'tis manifeſt that the horizontal Parallax is the greateſt; that the Parallax in Altitude decreaſes as the Elevation increaſes, and increaſes as the Diſtance from the Earth decreaſes.

Beſides the Parallax in Altitude thus deſcribed, there is alſo a Parallax in Latitude, and alſo a Parallax of Longitude, *&c.* to be conſidered, proceeding from the ſame Cauſe. This is repreſented in the azimuth Circle Z P D, and affects the Planets Places in the Zodiac: The Parallax in Latitude is P O, and that of Longitude is P Q. A juſt Knowledge of this is of great Uſe in calculating ſolar Eclipſes, and in finding of this much depends upon the Moon's Diſtance from the Nonogeſimal Degree.

By the annual Parallax of the Planets, or Parallax of the Earth's Orbit, is generally meant the Angle ſubtended at any given Object, by the radial Diſtance of any two oppoſite Points in the Earth's Orbit, called the Diameter of the *Orbis Magnus*, or of any other Chord; ſuch are the Earth's Angles of Elongation to all the ſuperior Planets, and thoſe of the inferior ones to the Earth. Beſides which, there are other Degrees of Parallax ariſing from the Planet's Inclinations or Heliocentric Latitudes, as LK, R S and U P, which vary its geocentric Quantity to every Poſition of the Earth.

The firſt of theſe Kinds are repreſented by the Angle C O B, M C B, Q K B, C K B, C N B, and C I B; of the latter by R T S, K Q L, L C K, L B K, V C p, and V Q P, *&c.*

Refraction, is the Bending, Change, or Removal of the Rays of Light and Viſion, and is greateſt near the Horizon, and through Vapours of the denſeſt Compoſition. *See the Atmoſphere explained, Page* 20.

The Planets, inſtead of their Names at Length, are often expreſs'd by theſe Characters, which are generally made uſe of either for Abreviation or otherwiſe, for want of Room, (*viz.*)

Sol	Is ſignified by	☉
Venus		♀
Mercury		☿
Luna		☾
Saturn		♄
Jupiter		♃
Mars		♂

The Earth is often denoted by ⊖

THE

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OF THE SYSTEM OF THE WORLD.

BOOK I.

SECT. I.

Of the Planets in general.

THE Sun, the ſole Fountain of Light and Heat, is plac'd in the common Focus of all the primary Orbits, and nearly in the Center of the Syſtem; with a Rotation round his own Axis from Weſt to Eaſt in the Space of 25 Days 6 Hours.

His Diameter is in round Numbers, neareſt *763,000 Miles, (how this is found will be ſhewn hereafter) and the Obliquity of his Axis to the Plane of the Ecliptic is about 83 Degrees.

Round him and their common Center of Gravity, the ſeveral Planets perform their Motions, revolving in elliptical Orbits, and are obſerved to complete their reſpective Periods, with Regard to the fixt Stars, nearly as follows:

---

* According to Mr *Whiſton*.

Periods of the Planets round the Sun.

Mercury in		87 Days	23 Hours	15 Minutes	54 Seconds
Venus		224	16	49	27
The *Earth*		365	5	48	
Mars	1 Year	321	23	27	
Jupiter	11 Years	317	12	20	24
Saturn	29 Years	174	6	36	

That is, in Days and decimal Parts,

♄ 10759.275	♃ 4332.514	♂ 686.9785
☉ 365.2565	♀ 224.6176	☿ 87.9692

Theſe Times are all found by the return of the Planets, in their Heliocentric Motion, to the ſame Point in the Heavens amongſt the zodiacal Stars.

The mean, or rather middle, Diſtances of all thoſe Planets from the Sun's Center, with reſpect to one another, have been determined, by the Help of *Trigonometry* comparing many Obſervations together, to be very nearly thus:

Proportional Diſtances of the Planets from the Sun.

By *Kepler*.	By *Bullialdus*.
☿ 38806	☿ 38585
♀ 72400	♀ 72398
♂ 152350	♂ 152350
♃ 519650	♃ 522520
♄ 951000	♄ 954198

Mean Diſtance of the Earth in like Parts 100000.

Kepler found out, and Sir *Iſaac Newton* has ſince demonſtrated, that the Squares of the periodic Times, and the Cubes of the mean Diſtances of the

Planets bear to one another a reciprocal Analogy, and ſrom this the above Numbers have been proved to be very near the Truth. (*viz.*)

As the Square of the periodic Time of any one Planet,
Is to the Square of the periodic Time of any other Planet;
So is the Cube of the mean Diſtance of the ſormer Planet,
To the Cube of the mean Diſtance of the Latter.

Thus confirmed,

The mean Diſtance of the Earth being ſuppoſed 100000 Parts, its Cube will be 1,000,000,000,000,000, and the periodic Time 365$^{d.}$ 5$^{h.}$ 48$^{m.}$ reduced into Minutes is 525968.5, and ſquared is 276642862992.25; of *Venus* the periodic Time is 224$^{d.}$ 16$^{h.}$ 49$^{m.}$ 27$^{s.}$, the Minutes 323569.4, and ſquar'd is 104697156616.36.

Now
As the Square of 525968.5, which is 276642862992.25
Is to the Square of 323569.4, which is 104697156616.36
So is the Cube of 100000 which is 1,000,000,000,000,000

$$\text{To } \frac{104697156616360000000000000.00}{276642862992.25}$$

Which will be 378456019012834.7; the Cube Root of which is 72333.3 *Venus*'s mean Diſtance from the Sun.

In like Manner, the Square of *Mars*'s periodic Time in Minutes, being 97839026137562,5 the Cube of his mean Diſtance will be found 3537446267659410; the Root as per Table, and ſo of all the reſt, *Viz.*

Of			
	♂	152369	mean Diſtance from the *Sun*.
	☿	38710	
	♃	520096	
	♄	954006	

Theſe Numbers found by the above proportional Properties, and ſo nearly agreeing with the former, deduced from Obſervation, is a ſufficient Proof of the great Truth of our preſent Theory of the Planets Motions.

The Planets being obſerved in different Parts of their Orbits to move faſter and ſlower, and to be much farther diſtant from the *Sun* at one time than at another, are found by Calculation, and confirmed by the Laws of Gravity, to circumvolve in elliptical Curves. And,

Their Orbits have been determined nearly as follows:

Dimenſions of the Planets Orbits, Viz.

	The Tranſverſe Semi-diameter.	The Conjugate.	Excentricity
Of *Mercury*	38710	37881	7970
Venus	72333	72331	517
The *Earth*	100000	99985	1732
Mars	152369	151715	14100
Jupiter	520110	519506	25050
Saturn	953800	952230	54700

Theſe Numbers being reduced into *Engliſh* Miles, by having given the Radius of the *Orbis Magnus* in Diameters of the Earth; which laſt is known, and the former eaſily found by Calculation; *tho' at preſent not quite ſo exact as we may hope for at the next Tranſit of* Venus *over the* Sun, *by reaſon of the great Difficulty in obſerving the true Parallax of very diſtant Bodies.*

The various Diſtances of the Planets from the *Sun*, in round Numbers will come out as follows:

Diſtances of the Planets from the Sun.

Of	In Perihelion.	The Mean.	In Aphelion.	Excentricity.
Mercury	25,280,000	32,000,000	38,720,000	6,720,000
Venus	58,587,000	59,000,000	59,413,000	413,000
The *Earth*	79,623,000	81,000,000	82,377,000	1,377,000
Mars	111,561,000	123,000,000	134,439,000	11,439,000
Jupiter	403,648,000	424,000,000	444,352,000	20,352,000
Saturn	734,265,000	777,000,000	819,735,000	42,735,000

Of the Diameters and proportional Magnitudes of the Planets.

The Diameter of	*Mercury*	Is found to be	4,240	Miles.
	Venus		7,900	
	The *Earth*		7,970	
	Mars		4,440	
	Jupiter		81,000	
	Saturn		61,000	

Saturn is encompaſſed with two Rings, which together are like the Horizon of an artificial Globe; their Diſtance from *Saturn* is nearly 24,500 Miles, and both together 21,000 Miles broad. But more of this in its proper Place.

We come at theſe Magnitudes from the Solution of a right angled Triangle, having firſt given the apparent Diameters of the Planets, and ſecondly their Diſtance from us: Thus,

As *Radius*, or Sine of 90 Degrees,
Is to the Logarithm of the Planet's Diſtance;
So is the Sine of half the Angle of Appearance,
To the true Semi-diameter of its Body.

From what is known above, Mr. *Whiſton* computes the ſuperficial Areas of the Planets to be nearly, in round Numbers, as follows:

The Surface, or ſuperficial Area

Of The *Sun*	1,813,200,000,000	Square Miles.
Saturn	14,000,000,000	
Jupiter	20,000,000,000	
Mars	60,000,000	
The *Earth*	200,000,000	
Venus	200,000,000	
Mercury	55,000,000	

At the ſame time he computes their Solidities to be,

Of the *Sun*	230,000,000,000,000,000	Cubic Miles.
Saturn	160,000,000,000,000	
Jupiter	280,000,000,000,000	
Mars	44,000,000,000	
The *Earth*	266,000,000,000	
Venus	264,000,000,000	
Mercury	39,000,000,000	

Theſe Bodies are all repreſented in Proportion to one another upon the great Scheme; but, to know exactly how many times one contains another, cube any two of their Diameters, and divide the greater by the leſſer. (*See* Euclid, *B.* 12. *Prop.* 18.)

Thus the Sun will be found to contain the Earth above 867568 times.

From the various Inequality of the planetary Motions, and their Diſtance from us, it is eaſy to conceive that their apparent Diameters can never be the ſame in all Poſitions; and, in all ſmall and very remote Bodies, their viſible Diameters nearly increaſe and decreaſe in the ſame Proportion as their Diſtances decreaſe or increaſe. But more mathematically: If the true Diameter of any Planet be given, and its Diſtance to any Part of its Orbit known; the Angle under which it will at any time be ſeen, may thus be found:

As the true Diſtance, or Vicinity of the Body,
Is to the Sine *Radius*, or 90 Degrees;
So is the real Semi-diameter,
To the Sine of the apparent One.

In this Manner it may be found, that the apparent Disk of the Sun to

		Deg.	Min.	Sec.
Mercury	is nearly	1	22	48
Venus			44	40
The *Earth*			32	24
Mars			21	20
Jupiter			6	12
Saturn			3	24

And in general, the Phænomena of theſe Planets from the Earth, are as follows;

Diameter of	In Perigeon.				Mean Diſtance.				In Apogeon.			
	2ds.	3ds.	2ds.	3ds.	2ds.	3ds.	2ds.	3ds.	2ds.	3ds.	2ds.	3ds.
Saturn	22	4	23	11	20	0	21	2	17	56	18	49
	17	58	19	5	16	1	18	3	14	6	14	58
Jupiter	47	4	48	22	39	30	40	34	31	56	32	46
	49	1	50	38	41	4	42	50	33	0	34	45
Mars	15	45	17	40	9	27	10	36	3	9	3	32
	18	20	20	21	11	0	12	10	3	40	4	5
Venus	72	0	84	2	41	39	48	36	11	18	13	12
	70	20			40	5	45	20	9	50	11	40
Mercury	13	30	16	20	9	41	11	43	5	52	7	6
	11	44			8	0	10	0	4	16	5	27

The *Stars.* 1. $\overset{\text{2ds.}}{\frac{6}{0}}$ 2. $\overset{\text{2ds.}}{\frac{5}{0}}$ 3. $\overset{\text{2ds.}}{\frac{4}{0}}$ 4. $\overset{\text{2ds.}}{\frac{3}{0}}$ 5. $\overset{\text{2ds.}}{\frac{2}{0}}$ 6. $\overset{\text{2d.}}{\frac{1}{0}}$

N. B. The Diameter of *Saturn*'s Ring in Apogeon, is $44^{2ds.}$ $48^{3ds.}$ in Perigeon $55^{2ds.}$ $12^{3ds.}$ and at a mean Diſtance $50^{2ds.}$ but rejecting all the ſcatter'd Light will be little more than $42^{2ds.}$

To know how much one Disk is larger than another, ſquare each apparent Diameter, and divide the greater by the leſs. (*See* Euclid *B.* 12. *Prop.* 2.)

Thus the Sun to *Mercury* will be found to appear $6,\frac{1}{10}$ times bigger than to us at the Earth.

All opaque Bodies, expoſed to the direct Light of any radiant Object, caſt Shadows behind them; and if the radiant Body be equal to the opaque one, the Shadow will be cylindrical (as at A in the Center Scheme); if leſs, the Shadow will increaſe, as at B; and if greater, diminiſh as at C. Thus the

Planets, being in themſelves dark Maſſes of terraqueous Matter, and Reflecting only the ſolar Light, carry along with them, in their Orbits, vaſt Voids in the Space oppoſite the Sun, which, if the Sun were either equal to, or leſs than, the Planetary Bodies, would obſcure every Object in that Direction, not having native Light of their own, as far as the Stars. But this has never yet been done; for *Jupiter* in *Syzygia* has never yet eclipſed *Saturn*, nor *Venus* the Earth; conſequently the Sun muſt be greater than either of them, and their Shadows *conical.* The Extent of theſe Privations of Light to every Planet is found by this *Canon*, *

As the Difference of the Semidiameters of the Sun and Planet,
Is to the Planet's Diſtance from the Sun's Center;
So is the Semidiameter of the Sun,
To the true Diſtance of the Shadow's Point from his Center.

Out of which ſubſtracting the Planet's Diſtance from the Sun, there will remain the Length of Shadow: Thus,

The Length of the Shadow

Of	In Perihelion. Miles.	Mean Diſtance. Miles.	In Aphelion. Miles.
Mercury	141,266	178,817	216,367
Venus	- - - -	617,266	- - - -
The *Earth*	840,476	855,021	869,558
Mars	652,986	719,941	786,896
Jupiter	- - - -	50,357,700	- - - -
Saturn	- - - -	67,516,935	- - - -

Venus, *Jupiter*, and *Saturn* having, proportionally, the leaſt Excentricity, I have omitted their greateſt and leaſt Shadows, as being of no great Conſequence.

Of

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* *Theorem.* Let the Planet's Diſtance from the Sun be d; the Sun's Semediameter e, and that of the Planet b. Then by *Euclid* of ſimilar Triangles $e-b : d :: e \frac{de}{e-b}$ and $\frac{de}{e-b} - d =$ Length of the Shaddow.

Of the Planets Denſities and Quantities of Matter, &c.

The Planets, tho' all of the ſame original Matter, yet differ very much in their Solidity, Union of Parts, or Hardneſs of their Compoſition; as Earth from Stone, or Stone from Glaſs; and this condens'd Maſs, or real Quantity of Matter, is in all Bodies proportional to their relative Gravities, *i. e.* to their Force of Attraction or gravitating Powers. And through all the Planets where the Ratio of this Virtue is in Effect known, the Quantity of Matter is thus determined.

The Quantity of Matter in the Sun, is to the Quantity of Matter in the Earth, in a Ratio compounded of the triplicate Ratio of *Mercury* or *Venus*'s Diſtance from the Sun, to the Moon's Diſtance from the Earth, and the duplicate Ratio of the periodic Time of the Moon, to that of *Mercury* or *Venus*, &c.

Hence the Ratio of the Quantity of Matter in the three Primary Planets, who have Secondaries, to the Quantity of Matter in the Sun, will be ſound to be as follows.

The Quantity of Matter

In the *Sun* is	227500
In *Saturn*	94
In *Jupiter*	220
And in the *Earth*	1

This being ſound, the Denſity of the Planets are to one another; in a Ratio compounded of the direct Ratio of their Quantities of Matter, and the invers Ratio of their Magnitudes, that is to ſay,

The Denſity of the Sun, is to the Denſity of the Earth, in a Ratio compounded of the Ratio of the Quantity of Matter in the Sun, to the Quantity of Matter in the Earth, and the Ratio of the Magnitude of the Earth, to the Magnitude of the Sun.

Hence the Denſity of the Sun will be, as 25.5
To 15, the Denſity in *Saturn*,
To 19, in *Jupiter*,
And to 100, in the *Earth*.

And their accelerating Gravity, or the Weight of equal Bodies, upon the Surfaces of each of them; which is in a Ratio compounded of the direct RaRatio of their Maſſes of Matter, and the inverſe Ratio of the Squares of the Diſtances from each reſpective Center, will be thus.

A Body at the Sun, weighing 10000 Ounces, Pounds, &c.
That ſame Body would weigh at *

		Per *Whiſton*, at the *Sun*	24.40
The *Earth*	1258.5	At the *Earth*	1
Jupiter	804.5	At *Jupiter*	2
Saturn	536	And at *Saturn*	1.28

It is eaſy to conceive from the Laws of Gravity, that every Planet muſt have a peculiar Sphere of Attraction of its own, whereby all heavy Bodies in theſe circumambient Regions, have a natural Tendency to their common Center; as a Stone, projected in the Earth's Atmoſphere, falls to the Earth again; and that there is always one Point betwixt any two Bodies, where Gravity ceaſes, and where a third would be at reſt. Thus there is ever one Place betwixt the Sun and Earth, &c. where neither has Power to act, conſequently, a Body there ſuſpended would reſt ſelf-balanc'd and free from falling either Way.

To find this Point of Equilibrium, between any two Planets, whoſe Diſtance aſſunder, and Quantity of Matter is known, this is the *Theorem*.

Let A and B be the two Bodies given, and let the Quantity of Matter in A be to that in B, as 10,000 to 100.

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* For the Demonſtration of all theſe Quantities, ſee *Gregory's* *Aſtron.* B. III. Prop. 48, 49, &c.

A 100, E D C 10 B

Lemma 1. At equal Diſtances from different Bodies, Gravity is as the Quantity of Matter.

Hence in the Point E, equally diſtant from A and B, any Body, weighing 10,000 towards A, will weigh but 100 to B.

Suppoſe the Semi-diſtance A E, or E B, then the $\sqrt{^2}$ 10000, = 100, and C B the Root of this Equal 10.

Lemma 2. Gravity to all Bodies decreaſes, as the Square of the Diſtance increaſes; & *vice verſa*. Hence the ſame Body in C will weigh 10,000 to B, that lately in E weigh'd 10,000 to A. Hence, in theſe two Points, E and C; Gravity is equal to both A and B: And ſince a third Point D muſt be found common to both, where Gravity to each will ceaſe, for D C put x.

And as, by *Lemma* 2d, $BC^2 : BD^2 :: AE^2 : AD^2$ alſo by *Euclid* 5. $bc : bd :: ae : ad$, and conſequently $10 : 10 + x :: 100 : 190 - x$. Hence $1000 + 100x = 1900 - 10x$ and x will be found $= \frac{900}{110} = 8.18$.

By this will be found, that the Radius of the Sphere of Attraction to

Saturn	is about	12,768,000	Miles.
Jupiter		12,879,000	
The *Earth*		* 173,746	

The Diſtances of the Planets from the Sun are ſo very immenſe, that were their projectile Forces to ceaſe, according to Mr *Whiſton*,

Saturn	Falling from its Orbit, would not arrive at the Sun in leſs than	190 Days.	
Jupiter		167	
Mars		121	
The *Earth*		64	10 Hours.
Venus		39	17
Mercury		15	13

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* In reſpect of the Sun: But here we may preſent a Quere, which will admit of ſome Diſpute; for ſince the Point of equal Attraction betwixt the *Earth* and the *Sun*, falls here conſiderably within the Moon's Orbit, we ſhould be inclined to believe with Mr *N. Facio*, that our preſent Knowledge of the Sun's Diſtance and Magnitude is not a little defective, and that the ſolar Syſtem is not near ſo extenſive as we imagine. *(See the Theory of the Earth and Moon.)*

And their Velocities round the Sun, are ſo very violent and rapid, (tho' not perceptible to us); that in the Space of one Hour,

Saturn	In its Orbit moves thro' the etherial Medium.	18,000	Miles.
Jupiter		24,000	
Mars		45,000	
The *Earth*		56,000	
Venus		70,000	
Mercury		100,000	

SECT. II.

Of the inferior Planets and the Sun.

Of the Sun.

THE Sun's apparent Diameter has been obſerved of late Years, in the *Abſides* of the Earth's Orbit, to be, when greateſt, $32^{min.}$ $48^{2ds.}$ and when leaſt $31^{min.}$ $42^{2ds.}$ the Anomalia being in the firſt Place 0, and in the latter 6 Signs. And, at a mean Diſtance from the Earth, Sir *Iſaac Newton* makes it $32^{min.}$ $15^{2ds.}$ But if *Mouton*'s Obſervations of the Sun's Diameter throughout the Year 1660, be true, which ſeem to have been made with great Accuracy, the Sun appears the leaſt, when, by his Theory, he ſhould not be ſo, namely in *March* and *September*.

For by a Pendulum's vibrating 9550 times in an Hour.

He found,	*September* the 21,	338.34	Vibrations perform'd, during the Sun's Tranſit over the Meridian.
	March the 25,	339	
	December the 24,	376.377	
	June the 22,	364.365	

Now as 955, is to 360;
So is each reſpective Number here found,
To the Seconds the Sun was in paſſing the Meridian at that Time.

And,
As 240 Seconds, is to 60 Minutes, or one Degree;
So is the Seconds thus found, to the Sun's apparent Diameter.

Hence ſubſtracting $5^{\text{2ds.}}$ for the Sun's momentary Advance, ariſing from the Earth's annual Motion in her Orbit,
The Sun's Diameter in *March*, will be found $31^{\text{min.}}$ $40^{\text{2ds.}}$
In *December*, $35^{\text{min.}}$ $22^{\text{2ds.}}$ and in *June* $34^{\text{min.}}$ $14^{\text{2ds.}}$

But in theſe Quantities, eſpecially the former, the Dilation of Light muſt be conſidered, in Proportion to the Elevation and Degrees of Refraction, which will make it ſomething leſs, the Sun being ſeen thro' a much denſer Medium near the Horizon than towards the Zenith.

If theſe Obſervations may be depended upon, I think this manifeſtly proves the Sun's viſible Form to be elliptical, and his Body an oblate Spheroid, which Sir *Iſaac Newton*, in ſome meaſure, concludes it muſt be from its Rotation round its Axis. Elſe how theſe apparent Contradictions will be accounted for, I have at preſent no Idea.

The Sun's horizontal Parallax, or the Semi-angle under which the Earth would appear to an Eye at the Sun, tho' much depends upon a true Knowledge of it, we have never yet been able to determine; the Minuteneſs of its Quantity, ariſing from the vaſt Diſtance of the two Bodies rendering it an almoſt inſurmountable Difficulty to obtain.

Mr *Caſſini* pretends to have made it $9^{\text{2ds.}}$

Dr *Gregory* makes it a Mean betwixt that of *Mercury* and *Venus*, *viz.* $12^{\text{2ds.}}$ and Sir *Iſaac Newton* in his *Principia*, has it a Mean betwixt this and the former, *viz.* $10^{\text{2ds.}}$ $30^{\text{3ds.}}$

Was its true Quantity known, the exact Diſtance of the Sun from the Earth might, by the ſimple Solution of a right-angled Triangle, be eaſily found, which hitherto hath only been attempted by the Parallax of *Mars* in Perigeon.

The Sun is frequently obſerved by the Help of Teleſcopes, (and ſometimes with the naked Eye in thick Weather), to have many dark Spots upon his Disk, which are ſuppoſed to be thrown out from his Body into his Atmoſphere, and are carried round him as in a Vortex. Some of theſe Spots continue for a long Space of Time, others are broke to Pieces or ſeparated, while the Eye is viewing them, tho' the leaſt of them are Maſſes of Matter, very near as big as our Earth. By the Revolution of theſe Spots along with the Sun, apparently from Eaſt to Weſt, the Sun is found to have a Rotation round his Axis, in 25¼ Days, from Weſt to Eaſt; the North Pole directing to 10 Degrees of *Piſces*, and the South to 10 Degrees of *Virgo*, with each 83 Degrees Latitude from the Ecliptic.

This Motion being oblique to the Plain of the Ecliptic, ſometimes the South Pole of the Sun, and ſometimes the North is ſhewn to the Earth, and thoſe Spots apparently deſcribe Elliptical Curves, all bending from the viſible Pole.

But when the Earth is in 10 Degrees of *Gemini*, or as many Degrees advanced in *Sagittarius*, which are the two ſolar equinoctial Points, both Poles will be ſo near the Sun's Verge, as to be neither viſible, at which time the Spots will paſs over the Disk, in the Direction of a right Line.

The Sun's circumambient Atmoſphere, on all Sides together, form a vaſt inflamed Region, called, or rather form that Medium from whence proceeds, the *Aura Ætherea*, and this luminous Sphere, chiefly produces our Morning *Aurora*, which generally ſhews itſelf in a ſemi-circular Figure, ſoon after the Dawn or Day-Break, and ſhines out moſt manifeſt in the Summer Mornings and Evenings, a little before Sun-riſe, and ſometime after he is ſet.

Beſides this agreeable Phænomenon of the *Aura Ætherea*, there is a third kind of pellucid Matter always attending the Sun, and proceeding from him, called the Zodiac Light. This was firſt taken Notice of by Mr *J. Childrey*, about the Year 1650; and was afterwards obſerved by Mr *Caſſini*, in the Year 1683, a little before the vernal Equinox.

This extends from the Sun, both ways along the Ecliptic, to ſometimes 60 and ſometimes 90 Degrees; it's greateſt viſible Breadth is about 30 Deg. and its two Extreams, where both Sides or Surfaces of it meet, form an Angle of 21 Deg. nearly. The Light of it is much like that of the *Milky Way*, and is pellucid, like the Tail of a Comet, and moſt conſpicuous about the End of *February* and the Beginning of *October*.

Mr *Caſſini* imagined this Brightneſs in the Heavens, to proceed from an infinite Number of little Planets near the Sun, ſtrongly reflecting his Light; Mr *Facio* ſuppoſed them a vaſt Collection of Corpuſcles, ſurrounding the Sun in the Form of a Lens; the greateſt Plain paſſing nearly parallel to the Ecliptic.

But, in all probability, the Particles that ſeem to fill up and form this luminous Space, may prove to be no other than the broken Pieces, or leſſer ſolar Spots diſpers'd all round the Sun, in the Direction of his Equator, and moſt fully reflecting his Light, as the inferior Planets do at their greateſt Elongation.

Hence according to the Obliquity of the Sun's Axis, it appears to deflect a little towards the North from the Ecliptic, and to be convex that way, the South Part not being ſo eaſily ſeen.

And from this alſo a Reaſon may be given, why both Sides of the Sun are not equally luminous.

Its greateſt Breadth can never be ſeen, unleſs in a total Eclipſe of the Sun of the greateſt Duration, and could its outward Elongation be nicely obſerved, where it is moſt viſible, its extremeſt Diſtance from the Sun may be ſound found by the Solution of a right-angled Triangle, in the ſame Manner as that of *Venus* or *Mercury*.

The apparent Diameters of the Planets, were they to be ſeen from the Sun, would be nearly as follows.

Saturn, under an Angle of	$18^{2ds.}$	By Mr *Huygens*	$27^{2ds.}$
Jupiter	40	———————	54
Mars	8		
The *Earth*	24	By Mr *Caſſini*	18
Venus	28		
Mercury	20		

The ſolar Zodiac, in which the Planets would appear to move, is about $15^{deg.}$ $40^{min.}$ broad.

The Velocity of the Sun's inflam'd Surface round his Axis, is nearly equal to 4000 Miles per Hour.

For the Planets mean horizontal Parallaxes, as ſeen from the Sun. *(See, to each his apparent Diameter, p.* 6).

Of Mercury.

MERCURY is the firſt Planet we know of in the Syſtem, and, by reaſon of his great Vicinity to the Sun, is ſeldom within the Sphere of our Obſervation, he was ſeen in the great Eclipſe of 1715; and *May* the 17th, 1736, at 9 o'Clock in the Evening, I ſaw him in Conjunction with *Venus*, diſtant about five Minutes of a Degree.

To *Mercury*, the *Sun* and *Venus* are the only two great Bodies of the Univerſe. He views *Venus* and all the reſt of the Planets, as we do *Saturn*, *Jupiter* and *Mars*; but *Venus* ſhines upon him with great Luſtre, and 'tis probable, her great Light in oppoſition to the Sun, ſerves him inſtead of a Moon.

To him the Sun appears above ſix times greater than to us at the Earth, but his *Nychthemeron* or natural Day is not yet known.

His geocentric prime Revolution, or Perigration, is perform'd in 46 Years, in which Period of Time he returns to the ſame Place in the Heavens, and may be found in his former Poſition in reſpect of the Sun.

Every 58 Days, he is nearly conjoin'd with the Sun, and his mean heliotric Motion is $4^{\text{deg.}}$ $5^{\text{min.}}$ $32^{\text{2ds.}}$ per Day.

Anno 1700, *December* the 1ſt.

Mercury's Aphelion, was in	♐	$12^{\text{deg.}}$	$51^{\text{min.}}$	$57^{\text{2ds.}}$
His aſcending Node in	♉	15	46	3
The Inclination of his Orbit,		6	53	56
Motion of the Aphelion and Node, per Year,				2½ by Sir *I. Newton.*

There are Aſtronomers who give the Nodes of this Planet, a yearly Motion of $1^{\text{min.}}$ $36^{\text{2ds.}}$ but upon no real Foundation.

His Horizontal Parallax from the Earth is found,

When greateſt to be	$27^{\text{2ds.}}$	$8^{\text{3ds.}}$
And his leaſt	10	14

Mercury appears thro' the Teleſcope, to be ſometimes round, and at other times gibbous, and in one Revolution round the Sun, has all the Phaſes of our Moon.

Of Venus.

VENUS is the ſecond Planet known in the Syſtem, and is the moſt ſplendid of all the Primary Planets, being often ſeen in the Day time, ſeveral Hours before Sun-ſet. At her greateſt Elongation from the Sun, ſhe generally ſhines with ſo great Luſtre, as to caſt a Shadow upon the Earth, (if the Moon be abſent).

When occidental to the Earth, ſhe frequently performs the Office of our Morning Star, becauſe ſhe then riſes with the Dawn, and is the laſt obſcur'd by the Sun, in this Quality the Poets call her *Lucifer*: When oriental to the Earth, ſhe as often becomes our Evening Star, as generally ſetting with the Cloſe of Day, and being the firſt viſible at the Approach of Night. In this Poſition ſhe is called by the Poets *Heſperus.*

Milton takes notice of her ſuperior Luſtre, in deſcribing his Evening in *Paradiſe* thus,

> Now came ſtill Ev'ning on, and Twilight grey
> Had in her ſober Livery all Things clad;
> Silence was pleas'd: *Now glow'd the Firmament*
> *With living Saphires:* Heſperus, *that led*
> *The Starry Hoſt, rode brighteſt*; till the Moon,
> Riſing in clouded Majeſty, at length,
> Apparent Queen, unveil'd her peerleſs Light,
> And o'er the Dark her ſilver Mantle threw.

She is the moſt regular of all the erratic Stars, but has the greateſt geocentric Latitude from the Ecliptic, it being ſometimes equal to 9 Degrees.

To *Venus*, the Sun and the Earth are the greateſt apparent Bodies in the Univerſe, unleſs ſhe has a Moon, which indeed moſt Aſtronomers now are apt to believe ſhe has; for Mr *Caſſini* twice ſaw a ſmall Star very near her, which he ſuppoſed to be a Satellite; firſt he ſaw it in the Year 1672, and again it appeared very diſtinctly thro' a 34 Foot Teleſcope, *Auguſt* the 28th, 1686, $16^{h.}$ $15^{min.}$ P.M. (*i. e.* about a Quarter paſt four in the Morning) And ſince, ſeveral very able Aſtronomers have imagined, they have ſeen the ſame: It ſhew'd the ſame Phaſe as *Venus* did, and appeared to be diſtant from her, about $\frac{3}{5}$ of her Diameter, its Magnitude about $\frac{1}{4}$ of *Venus*'s Diameter.

Mercury appears to *Venus*, as *Venus* does to the Earth, and the Sun appears to *Venus* near thrice as big as to us.

Venus is conjoin'd with the Sun, every 292 Days, and her mean heliocentric Motion is $1^{deg.}$ $36^{min.}$ $7^{2ds.}$ per Day.

Her prime Revolution geocentric is perform'd in 8 Years.

And Anno 1700, *December* 31.

Her Aphelion was in	♒	$4^{\text{deg.}}$	$9^{\text{min.}}$	$23^{\text{2ds.}}$
Inclination of her Orbit		3	23	0
The aſcending Node in	♊	14	32	22
Her aphelial Motion, per Year				6½

In ſome aſtronomical Tables, there is a Motion given to her Nodes of $37^{\text{2ds.}}$ per Annum.

Her mean horizontal Parallax, ſeen from the Earth, hath been made $56^{\text{2ds.}}$ $31^{\text{3ds.}}$ but her true greateſt (tho' much wanted) is not yet known.

She is obſerved to turn round upon her Axis, in 23 Days 8 Minutes.

And the Obliquity of her Poles, to the Plain of the Ecliptic, is judg'd to be $85^{\text{deg.}}$

SECT. III.

Of the Earth and Moon.

Of the Earth.

THE Earth our preſent Habitation, you'll find ſituated in the Syſtem between the Orbit of *Mars* and that of *Venus*.

It's Diameter is neareſt	7969.2	Miles.*
And Circumference	25035.8	

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* *Eratoſthenes* was the firſt who attempted the Meaſure of the Earth, which he ingeniouſly effected thus, he firſt made choice of two remarkable Cities, both under the ſame Meridian, namely *Alexandria* and *Siene*. Secondly, at the Moment he knew the Sun to be vertical to the one, he carefully obſerved his Zenith's Diſtance at the other, which he found to be 7 Deg. 12 Min. then from their known Diſtance aſſunder, *viz.* 5000 Furlongs, he found the Circumference of the Earth,

i. e.

The *Atmoſphere* or fluctuating Region of all exhal'd Vapours, in its greateſt Degree of Elevation or elaſtic Levity, is never above 60 Miles high, or in its moſt compreſs'd or denſe State leſs than 40. Its Height at any time may be found by the Solution of a right-angled Triangle, knowing the Sun's Depreſſion below the ſenſible Horizon, at the Beginning or End of the *Crepuſculum*. (*See the Earth and her Atmoſphere*, *Tab.* III.)

The Twilight generally commences, or diſappears when the Sun is advanc'd within 18$^{deg.}$ of the Horizon, or depreſs'd as much below it.

Let E repreſent the Sun in the Horizon at *d*, and 18$^{deg.}$ below the Horizon of *e*, at which time L will be the higheſt Point of the Atmoſphere, reflecting Light upon the Earth, and will then be in the Horizon of *e*; biſect the Angle *e* L *d*, and there will be given, in both the ſimilar rectangled Triangles, the Radius of the Earth, and the Angle at *g*. Hence *g* L may eaſily be found, and conſequently the Exceſs above the Earth's Surface may be known; but this Exceſs never continues the ſame, and as this changes the Angles muſt alſo vary.

At the End of the Year 1700.

	ſ.	deg.	min.	2ds.
The Earth's mean Anomalia was	3	20	43	50
The Aphelion in ♑	9	7	44	30
Mean Motion in 20 Julian Years,	240	0	9	4
In reſpect of the fix'd Stars,	239	29	52	24
Difference in the Proceſſion of the Equinox for that Time,			16	40
Which take from the ſinodical Motion of the Apogeon,		4	21	0

And

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i. e. as 7 Deg. 12 Min. was to 5000 ſo was 360 Deg. to the Thing requir'd. (*See* Euclid, *B.* I. *Prop.* 27.)

The Meaſure of the Earth has ſince been determined by many, in particular the Quantity of one Degree, which gives by Analogy the Whole;

Dr *Barnard* found the Quantity of a Degree,
To be 73.14 *Engliſh* Miles.
67.4 *Catholick* Miles.
And 66,$\frac{2}{3}$ *Arabick* Miles.
Mr *Norwood* concluded, a Degree muſt contain
69.5 Miles *Engliſh*, and
Mr *Picard* made a Degree equal to 69$\frac{9}{11}$ Miles, or
To = 365,184 Feet,

And for the ſame Time will remain the ſiderial Motion, $4^{\text{min.}}$ $20^{\text{2ds.}}$ of the Aphelion.

But Sir *Iſaac Newton* in his Principia makes this, for the ſame Space of Time, but $3^{\text{min.}}$ $32^{\text{2ds.}}$ or rather ſeems to deſtroy the former and produces another of $10^{\text{2ds.}}$ $36^{\text{3ds.}}$ per Annum in its ſtead.

The Earth's ſiderial or periodical Revolution round the Sun, is perform'd in reſpect of the fix'd Stars,

In $365^{\text{days.}}$ $6^{\text{hours.}}$ $9^{\text{min.}}$ $14^{\text{2ds.}}$

But the Time it takes up in paſſing from any one Point of the Ecliptic, and returning to the ſame again, which is call'd the * natural or tropical Year,

Is $365^{\text{days.}}$ $5^{\text{hours.}}$ $48^{\text{min.}}$ $57^{\text{2ds.}}$

The Earth's mean daily Motion in her Orbit is $59^{\text{min.}}$ $8^{\text{2ds.}}$
And per Hour, when ſloweſt $2^{\text{min.}}$ $23^{\text{2ds.}}$ faſteſt $2^{\text{min.}}$ $33^{\text{2ds.}}$ and the mean 2 28

The Viciſſitude of Day and Night is made by a Rotation of the Earth, round her own Axis from Weſt to Eaſt, and by Virtue of which all external Bodies, ſuch as the Stars and Planets appear to move altogether from Eaſt to Weſt.

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* This has ever been Matter of much Obſervation amongſt the Aſtronomers, and has been variouſly determin'd as follows, *viz.*

	D.	H.	M.	S.		D.	H.	M.	S.
Philolaus concluded it to be	365	0	0	0	*Hipparchus* and *Ptolomy*	365	5	55	12
Harpalus made it	365	12	0	0	*Galen*	365	5	45	36
Democritus	365	6	9	0	*Albategnius*	365	5	57	36
OEnopides,	365	9	0	0	*Azaphius* and *Avarius*	365	5	49	30
Meton,	365	6	19	0	*Alphonſus*	365	5	48	15
Calippus, *Archimedes* and *Ariſtarchus*	365	6	0	0	and *Capernicus*	365	5	47	29

The *Indians* and *Jews* made it 365 d. 5 h. 48 m. and the *Perſians* the ſame as *Copernicus*, from whence *Maſſahalah* made his Tables of the Sun's mean Motion. The Correctors of the old *Egyptian* Calendar have it 365 d. 5 h. 49 m. 11 ſ.

While——She from Weſt, her ſilent Courſe advance,
With inoffenſive Pace, that ſpinning ſleeps
On her ſoft Axle.——— Milton.

This, in reſpect of the Sun and true equal Time, is performed in 24 Hours, but with regard to the Stars, and the ſame equal Meaſure of Time in $23^{h.}\ 56^{m.}$

The Velocity of the Earth's equatorial Surface, is above 1000 Miles per Hour.

Sir *Iſaac Newton*, ſuppoſing the Earth to be made originally of a fluid Matter (tho' now condenſed to a very hard Subſtance), from the Laws of Motion affected by the centripetal Force, proves it to be of an oblate ſpheroidical Figure, and by the ſame Principles he proves all the reſt of the Planets, leſs or more, to put on the ſame Figure.

The polar Diameter he finds to be in Proportion to the equatorial one, nearly as 229 is to 230, the Difference in Miles being $17\frac{1}{6}$. Hence the Quantity of a Degree near the Poles, will be ſomething leſs than that of one at the Equator, but not ſenſible enough to be taken notice of, in the common Solution of geographical Problems.

The Obliquity of the Earth's Axis, to the Plain of the Ecliptic, has been obſerved of late Years to be * $66^{deg.}\ 31^{m.}$

The

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* The Quantity of this Obliquity ſeems to have continually increaſed from the following Obſervations, made of the Sun's greateſt Declination, but how far they may be depended upon, we leave to be farther conſider'd.

	Deg.	Min.	Sec.	
Ariſtarchus and *Aratus* found it	24	0	0	
Hipparchus, and *Eratoſthenes*	23	51	30	
Ptolomy	23	51	30	*Anno Dom.* 140.
Almamon King of *Arabia*, *Machometes Aratenſes*, and *Albategnius*	23	35	0	from 740 to 900.
Arzahel the *Spaniard*	23	34	0	1070.
Almehon, Son of *Albumaſar*	23	33	30	1140.
Prophatius the *Jew*	23	32	0	1300.
Purbachius and *Regiomontanus*	23	29	30	1480.

But of later Years by *Copernicus* 23 deg. 28 min. 30 ſec. by *Tycho*, 23 deg. 31 min. 30 ſec. by *Johannes Warneres*, and *P. Nonias*, 23 deg. 28 min. 30 ſec. by *Hevelius* 23 deg. 30 min. 20 ſec. by *Mouton* and *Ricciolus* 23 deg. 30 ſec. and by Mr *De la Hire* 23 deg. 29 min.

The Figure of the Earth being more gibboſe, near the Equator, than at the Poles, is found to have occaſioned a great and notable Change in the general Poſition of the Stars, with reſpect to the Circles of the Sphere; by which the equinoctial Points, which were formerly placed at or near the firſt Star of *Aries*, have appeared to go backwards, as moving in antecedentria, and is perpetually receding at the Rate of $50^{2ds.}\ 0^{3ds.}\ 40^{4ths.}$ per Year, inſomuch that the Pole-ſtar in uſe at the Creation, is now removed above 20 Degrees from its primitive Situation.* This has ever been Matter of the choiceſt Speculation, ever ſince Aſtronomy came to any Maturity, and has always employ'd the niceſt Obſervers, in all Ages to determine its true Quantity. But the real Cauſe from whence it proceeded, was never diſcovered till Sir *Iſaac Newton* having found out, and ſolv'd a like retrograde Motion of the Moon's Nodes took it into Conſideration.

Of the Moon.

THE Moon is the moſt irregular of all the heavenly Bodies, by reaſon of her Orbit daily changing its Poſition to the Earth, and perpetually varying its elliptical Form or Species. The Regulation of her Motion being ſubject to ſo many Irregularities ariſing from the Laws of Gravity or mutual Tendency of all material Bodies, has employ'd the greateſt Skill of the ableſt Philoſophers and the very beſt Aſtronomers to effect; which before Sir *Iſaac Newton*'s Time was almoſt deſpair'd of, and is not compleated even now. The

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* In the Time of *Thales*, 634 Years before Chriſt, the firſt Star of *Aries* was in 28 deg. of *Piſces*, and about the Year of the World 3517, it was ſeen by *Meton*, at the Beginning of *Aries*. Since *Timocharis* 300 Years before Chriſt, obſerved it in *Aries*, 2 deg. 24 min. and *Hipparchus* in 4 deg. 40 min. at which Time the Pole-Star was diſtant from the Pole about 12 deg. 24 min, which *Ptolomy* afterwards found to be but 3 deg. *Albumaſar* found the firſt Star of *Aries* in 17 deg. 50 min. of *Aries*; *Alberenus* the ſame in 18 deg. 10 min. *Arzachel* in 19 deg. 37 min. Anno Dom. 1090; *Alphonſus* in 23 deg. 48 min. And *Copernicus* in 27 deg. 21 min. and from theſe the Proceſſion of the Equinoxes have been determined as follows.

By *Albategnius* 1 deg. in 66 Years.
By *VlughBeigh* 1 deg. in 70 Years.

By	D.	M.	S.	T.	
Tycho	1	25	00	00	By 100 Years.
Copernicus	1	23	40	12	
Ricciolus and *Flamſtead*	1	23	20	00	
Street	1	20	00	00	
Bullialdus	1	24	54	00	
Hevelius	1	24	56	50	

The greateſt Diſtance of the Moon from the Earth, when her Orbit is near its middle State of Excentricity,

Is about	253,000 Miles.
Its leaſt Diſtance	227,000
The mean Diſtance	240,000 by Mr *Whiſton.*
And Excentricity	13,000

But of ſuch Parts as her mean Diſtance from the Earth,

Is 10,000. The other Dimenſions of her Orbit is ever varying and putting on a new Figure in Proportion to the following Excentricities.

Viz.	From the leaſt	433
	And the Mean	563
	To the greateſt	668

In Proportion to that of the Earth, her true Diameter, is as 100 to 365, and Mr *Whiſton* makes it 2170 Miles.

Her mean Perigeon Shadow, in Conjunction with the Sun, her Diſtance from the Earth, being then about 56 Semidiameters of the Earth, and the Earth in Aphelion,

Is nearly 234,303 Miles.

The leaſt, or Apogeon Shadow is 226,374 Miles. Being then diſtant from the Earth about 65 Semidiameters, and the Earth in Perihelion.

Her mean 230,333 Miles.
And in Oppoſition 231,708 in both being $60\frac{1}{2}$ Semidiameters of the Earth diſtant from us, and the Earth at a mean Diſtance from the Sun.

Her mean ſiderial Revolution is performed in the Space
Of $27^{\text{days.}}$ $7^{\text{hours.}}$ $43^{\text{min.}}$

And her mean Sinodical one in $29^{\text{d.}}$ $12^{\text{h.}}$ $44^{\text{m.}}$

The Obliquity of her Orbit, the Nodes being in *Syzygia*;
Is $5^{deg.}$ $17^{min.}$ $20^{2ds.}$

But when the Moon is in *Syzygia*, and the Nodes in Quadrature,
It is only $4^{deg.}$ $59^{min.}$ $35^{2ds.}$

The Moon's Form nearly reſembles that of an Egg; the longeſt Axis exceeding the ſhorter about 186 Feet. And the eaſieſt Way (of the many made uſe of) to determine the Quantity of Matter in the Moon, to that in the Earth, is as follows.

To find the Quantity of Matter in the Moon.

Procure two Obſervations of the apparent Diameter of the Sun; one at the Time of the new Moon, the other at the Full, and both as near the ſame Place in the Heavens as poſſible: Then, as the apparent Diameter of the Sun nearly increaſes, as the Diſtance decreaſes, *&c.* it will be,

As the Sine of the leaſt Angle,
Is to the known middle Diſtance of the Earth, from the Sun in that Point;
So is the Sine of the mean Angle, *i. e.* of the two Obſervations,
To the extream Diſtance of the Earth in the ſame Point.

And the leſſer Diſtance taken out of the greater, leaves the true Excentricity, or Diſtance of the Earth's Center, from the common Center of Gravity of the Earth and Moon.

Now,

As the Moon's Diſtance from the Earth, in any Part of her Orbit, from her Theory is known; and the Ratio of the Earth and Moon's Gravity towards the Sun being, nearly, as their Diſtance from the common Center of Gravity inverſly; the Quantity of Matter in the Earth to the Quantity of Matter in the Moon may be thus determined, *i. e.*

As the Line of the Moon's Diſtance, } From the common Center.
Is to the Line of the Earth's Diſtance, }
So is the Maſs of Matter in the Earth,
To the Maſs of Matter in the Moon.

Thus the Matter in the Moon, to the Matter in the Earth, will be found nearly,
As 1,
To .02531, *i.e.* $\frac{1}{39.5}$

Then, the accelerating Gravity at the Moon's Surface, being to the accelerating Gravity on the Earth's Surface, in a Ratio compounded of the ſimple Ratio of the Quantity of Matter in the Moon, to the Quantity of Matter in the Earth, and the duplicate Ratio of the Semidiameter of the Earth, to the Semidiameter of the Moon; the Weight of a Body on the Moon, to the Weight of the ſame, or an equal Body on the Earth will be,
As 630 on the Moon's Surface,
To 1258 on the Earth's Surface.

And the Denſity of the Earth to the Denſity of the Moon, will be
As 100 to 123.5.

The Moon having no real Rotation round her own Axis, but what relatively, in reſpect of the Sun, proceeds from her Motion round the Earth, it follows, that her *Nychthemeron*, or natural Day, muſt of Conſequence, be exactly equal to her ſinodical Revolution, *i. e.* to 29 Days, *&c.* The mean diurnal or nocturnal Arches, being nearly 14 Days each.

But the Obliquity of the Moon's Orbit, to the Plain of the Ecliptic, being at a Mean 5 Degrees, there is always a conſtant Libration of Light, near the ſolar Horizon; which makes not only a ſmall Viciſſitude in the Lunar Days, to different Parts of the Moon, but likewiſe ſome material Difference in the Change of Seaſons, like thoſe of our Earth; ariſing from the Poſition of the Nodes at different times of the Year.

This Alteration upon the Moon's Diſk, view'd from the Earth, is call'd, the Moon's Libration in Latitude, and always obtends an Angle at the Moon's Center, equal to her Diſtance from the Ecliptic.

Beſides this, the Moon's Orbit being excentric, with regard to the Earth, there is alſo a Libration of the Longitude, which would not be, if the Moon mov'd in a perfect Circle. This Change of Phænomena, by which the Moon endeavours to turn away her Face, altering the Poſition of the Spots upon her Disk, that are towards us, is always greateſt at the Moon's middle Diſtance from the Earth, and leaſt of all, or rather none at all in the Abſides, *i. e.* the Apogeon or Perigeon Points.

To find this, there is always given the Moon's Excentricity, Diſtance, and Anomaly, and it may be determined by a Solution of the 5th Caſe of plain oblique Triangles.

At the End of the Year 1700.

			Deg.	Min.	Sec.
The Moon's Anomaly was in	♒		15	21	00
The Place of her Apogee	♓		8	20	00
And her aſcending Node in	♌		27	24	20
Revolution of the Apogee	8 years.	339 d.	8 h.	58 min.	direct.
———— of the Node,	18	224	3	0	retrograde.

	Sign	Deg.	Min.	Sec.	
Annual Motion of the Apogee,	1	10	39	50	
——————— of the Node,	0	19	19	43	
Motion of the Node per Day,	0	0	3	11	
The Moon's mean daily Motion is	0	13	10	35	in Longitude.
In Anomalia per Day	0	13	3	54	
The Difference is the daily Motion of the Apogeum			6	41	
The Moon's mean hourly Motion is	0	0	32	56	And *Minute* 33 ſec.
In the *Syzygia*, at a mean Diſtance from the Earth, Sir *Iſaac Newton* makes it			33	32	32 3ds.
And in the Quadratures, its mean Quality			32	12	2

	Min.	Sec.
At the ſame Time he makes the Quantity of		
Her Horizontal Parallax, *i. e.* in *Syzygia* to be	57	30
And in the Quadratures,	56	40
To the firſt Place her mean Diameter,	31	30
And to the laſt,	31	3
But her leaſt Diameter is about	29	10
Her greateſt, nearly	33	20
Her greateſt Parallax	61	16
And the leaſt	53	30

The principal Phænomena to an Obſerver at the Moon, are theſe; Our Earth always appears ſtationary, in point of Poſition and Elevation, but the Stars are altogether continually approaching her on one Side, and retiring from her on the other, ever retreating and advancing by a ſlow Motion equal to that of the Moon's thro' the Zodiac.

The Poles of the World, by a librating Motion, alternately ſhow themſelves upon the Diſk of the Earth, and the apparent Revolution of the moſt remarkable Kingdoms, ſerve the lunar Inhabitants, (*if any ſuch there be*) for an horary Sun-dial.

The Earth's apparent mean Semidiameter to the Moon,
Is $57^{\text{min.}}$ $18^{\text{2ds.}}$

The Sun riſes on the Moon 235 Times in 19 Years,
And the fix'd Stars 254 Times.

The heavenly Bodies move very ſlow, near the lunar Horizon, and amazingly faſt near the Meridian.

The mean Velocity in her Orbit is about 2400 Miles per Hour.

The mean menſtrual Parallax of her Orbit, is about $10^{\text{min.}}$ and her Globe would fall to the Earth by its natural Gravity, in about $4^{\text{d.}}$ $20^{\text{h.}}$

The Point of Suſpenſion, or of equal Attraction betwixt the Moon and the Earth, I make 8.27 Semidiameters of the Earth from the Moon's Center.

SECT. IV.

Of the ſuperior Planets.

Of Mars.

MARS is the fourth Planet in the Syſtem, and is the firſt of the ſuperior ones; he is of a fiery red Colour, and appears thro' the Teleſcope, to give a confus'd glaring Light, (not unlike the Nebuæ or cloudy Stars); in Oppoſition to the Sun he comes very near the Earth, and then ſhines almoſt as bright as *Venus*.

Mr *Huygens*, in the Year 1656, thro' his great Teleſcope of 130 Feet, obſerved ſeveral cloudy Spots to croſs his Disk in right Lines, like Belts or Faſcia; from whence he found him to have a Rotation round his Axis, in 24 Hours, 39 Minutes, and is judged to have an Atmoſphere like our Earth. ***(See the Scheme)***

The Sun appears to *Mars*, as much leſs than to us, as to *Venus* he appears bigger; *Venus* and the *Earth* appear to him as *Mercury* and *Venus* appear to us, but *Mercury* by reaſon of his Nearneſs to the Sun, never comes under his Obſervation.

His Axis is nearly perpendicular to the Plain of his Orbit, and the Velocity of his equatorial Surface round it, is nearly 500 Miles per Hour.

His prime geocentric Perigration, is performed in the Space of 79 Years.

Mars is alternately, either in Conjunction or Oppoſition to the Sun, conſequently in Apogeon or Perigeon, nearly, every 390 Days; his mean heliocentric daily Motion, is 31$^{\text{m.}}$ 27$^{\text{2ds.}}$ and ſometimes in the Abſence of *Venus*, he performs (but not ſo naturally) her Office of Morning and Evening Star.

At the End of the Year 1700,

		Deg.	Min.	Sec.
His Aphelion was in	♍	0	19	0
The Inclination of his Orbit		1	51	0
The aſcending Node in	♉	18	5	0
Siderial Motion of the Aphelion, per Year				20

But ſome give the Node and the Aphelion a Motion of $43^{2ds.}$ per Year.

His greateſt horizontal Parallax, is $37^{2ds.}$ $34^{3ds.}$

Of Jupiter.

JUPITER is the fifth Planet in the Syſtem, and the ſecond ſuperior one to the Earth; he is of a bright ſilver Colour, and much bigger, both in Reality and Appearance than any of the other revolving Planets; but not ſo refulgent as *Venus*. He is obſerved to have ſeveral dark Spaces upon his Disk like Zones or Belts about him; and is found to have a Rotation round his Axis, in $9^{h.}$ $56^{m.}$ by which violent Motion in ſo large a Body, his extream equatorial Parts move with a Velocity of above 25,000 Miles per Hour. His Axis is nearly perpendicular to the Plain of his Orbit, and his Polar Diameter, to that of his Equator is nearly as * 9' is to 10⅓.

Jupiter is ſo far removed from the Neighbourhood of the Sun, that he ſees, (*i. e.* his Inhabitants) neither *Mars* nor the *Earth*, *Venus* nor *Mercury*, to him the Sun appears five times leſs in Diameter, than to us at the Earth, and his horizontal Parallax is about $20^{2ds.}$

When *Venus* becomes heliacal, this Planet alſo often performs the Office of our Morning and Evening Star, according as he happens to be oriental or occidental to the Sun.

And ſometimes when he is in the one Situation and *Venus* in the other, one of them will be the Evening and the other the Morning Star, for the ſame nocturnal Revolution.

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* Or as 33 Sec. 25 Thirds to 36 Sec. 25 Thirds. His mean apparent Diameter perfect, is 37 Sec. 15 Thirds.

His prime geocentric Perigration, is performed in the Space of 83 Years.

Every 199 Days, *Jupiter* is either in Oppoſition or Conjunction with the Sun, and his mean heliocentric Motion is $4^{m.}$ $59^{2ds.}$ per Day.

At the End of the Year 1700,

		Deg.	Min.	Sec.
His Aphelion was in	♎	8	58	48
The Inclination of his Orbit is		1	22	
His aſcending Node is now in	♋	7	17	48
And it has a Motion given it of				13 per Year.

Jupiter is obſerved to have four Satellites or leſſer Bodies attending his Globe, each performing to him the Office of Moon, like that of our Earth.

Mr *Bradley* makes the Diameter of the firſt $\frac{1}{24}$ of the 2d $\frac{1}{27}$ of the 3d $\frac{1}{21}$ and of the 4th $\frac{1}{28}$ of *Jupiter*'s Diameter.

Their Periods and Diſtances are found to be as follows, *viz.*

The	Is diſtant from the Center of *Jupiter.*	Of his own Semidiameters, as obſerved by Mr *Pound.*
1ſt		5.965
2d		9.494
3d		15.141
4th		26.64

From the periodic Times they are found to be, the firſt, 5.667, the 2d, 9.017, the 3d, 14.384, and the 4th, 25.3.

Mr *Whiſton* makes the	To be diſtant from *Jupiter*'s Center	Miles.
1ſt		218,000
2d		348,000
3d		554,000
4th		972,000

Their Revolutions round him are nearly, thus,

The	is made in	*Periodical.* D.	H.	M.	S.	*Sinodical.* D.	H.	M.	S.
1ſt		1	18	27	34	1	18	28	36
2d		3	13	13	42	3	13	17	54
3d		7	3	42	36	7	3	59	36
4th		16	16	32	9	16	18	5	13

Their greateſt Elongations from him, at a mean Diſtance from the Earth,

	M.	2ds.	3ds.
Are reſpectively	1	51	6
	2	56	47
	4	42	0
	8	16	0

And their Velocities round him

Are	32,000	Miles, reſpectively per Hour, by Mr *Whiſton*.
	26,000	
	20,000	
	15,000	

The Radius of *Jupiter*'s Disk appears

		Deg.	M.
To the	1ſt,	10	1
	2d,	6	20
	3d,	4	5
	4th,	2	23

And were they to drop from their Orbits,

		Days.	Hours.
The 1ſt	would fall to *Jupiter* in	0	7
2d		0	15
3d		2	6
4th		2	23

All theſe little Planets, ſeparately or together, become inviſible to an Eye at the Earth, in three different Situations or Poſitions, with reſpect to the Body of *Jupiter*; Firſt by being eclipſed in the Shadow, ſecondly, in paſſing behind the Body of *Jupiter*, and thirdly, by being before him in croſſing his Disk.

They all move nearly in the ſame Plain, inclin'd to that of *Jupiter*'s Motion, in an Angle of $2^{\text{deg.}}\,55^{\text{min.}}$ and the aſcending Nodes are in $11^{\text{deg.}}\,30^{\text{min.}}$ of ♒, but were obſerved about the Year 1700, to be in $15^{\text{deg.}}$ of ♒. But the fourth Satellite has been obſerved to have ſomething leſs Latitude, the Inclination of its Plain, being but about $2^{\text{deg.}}\,40^{\text{min.}}$ and alſo has been ſeen to paſs ſometimes free from the Shadow

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Shadow, *&c.* as it did in the Year 1684, *October*, *November*, and *December*. (*See* Philoſophical Tranſ. N° 154)

The Immerſions of his Satellites, are only viſible at the Earth, when he is oriental to the Sun, *i. e.* from the Oppoſition to the Conjunction, and their Emerſions when occidental, *i. e.* from the Conjunction to the Oppoſition.

The different Periods of *Jupiter*'s Moons, produce four kinds of Months,

Of one of which there are	2407	in a Year.
Of another of which there are	1203	
A third making	600	
And a fourth	254	

Of Saturn.

SATURN is the laſt and higheſt known Planet in the Syſtem; he is of a heavy dull Lead Colour; but when ſeen thro' a good Teleſcope, the moſt remarable Planet in the Heavens.

He is obſerved to be encompaſs'd with a luminous Ring, like the artificial Horizon of a Globe, equally reflecting the Sun's Light with his Body.

The Obliquity of the Plain of this Ring with that of the Ecliptic, is about $23\frac{1}{2}^{\text{deg.}}$ (ſome have made it $31^{\text{deg.}}$) and its Nodes or Interſection with the ecliptic Plain, is in $20^{\text{deg.}}$ $30^{\text{min.}}$ of ♓ and of ♍, in one of which Points, Anno 1659, *Chriſtian Huygens* obſerved the Ring to lie croſs the Disk of *Saturn*, forming a dark black Line, the extream Verges of it, not reflecting the Sun's Light.

Out of this Plain, the Ring being a perfect Circle round *Saturn*'s Body, its Perſpective is of Conſequence an Ellipſis, and leaſt excentric, the farther *Saturn* and the Earth are removed from its Nodes. When moſt open, *viz.* in $20^{\text{deg.}}$ and a half of ♊ or of ♐, its outward tranſverſe Diameter is to the Conjugate nearly, as 3 is to 1. The Space betwixt the Ring and *Saturn*'s Globe is nearly equal to the Breadth of the Ring itſelf, (*ſee p.* 5.) and thro' this vacant Space ſome of the ſmalleſt fixed Stars have been ſeen.

But

But at all Times *Saturn* ſeems not to be the true Center of this Ring, by reaſon, it has been obſerved in ſome Poſitions, to be more diſtant from him on one Side than on the other; from hence it may be argued, to have a Rotation round him like to a Satellite.

Thus far I have deſcrib'd this Ring, as ſuppoſing it form'd of one united Piece of Matter; but thro' the beſt Teleſcopes, it appears to be made up of many Rings, of which two are very viſible, and a third perceptible. Theſe I ſaw thro' a five Foot Focus Reflector (made by Mr *Jackſon*) 1739, in *March*; the outward one being to the inward one as 1 to 3, but the reſt were very obſcure: At this Time the Ring appear'd moſt open.

The principal Phænomena of this Ring, to the Inhabitants of *Saturn* muſt be theſe,

To one Part of his Globe, at one time it appears like a bright luminous ſemicircular Arch, riſing and terminating in oppoſite Points of the Horizon, and ſometimes ſeparated into two Parts, like the oppoſite Projection of a broken Pediment, or the Beginning and End of a Rain-bow, one Part viſible in the Eaſt, the other in the Weſt. And at the ſame Time to other Parts of his Globe, like one entire luminous Segment of a Circle, riſing above the Horizon, like an Arch of the *Aurora*.

To two Zones of *Saturn*'s Body, each 53$^{\text{deg.}}$ broad, this Ring is never ſeen at all, by Reaſon of its great Parallax.

To *Saturn* the Sun appears ten times leſs in Diameter than to the Earth, and *Jupiter* is the only Planet (except the Sun) viſible to his Inhabitants; *Jupiter* appears to him as *Venus* does to the Earth. His prime Revolution or geocentric Perigration is perform'd in 59 Years.

Every 189 Days, he is either in Oppoſition or Conjunction with the Sun, and his mean heliocentric Motion, is 2$^{\text{min.}}$ 1$^{\text{2d.}}$ per Day.

At the End of the Year 1700,

		Deg.	Min.	Sec.
His Aphelion was in	♐	27	32	36
The Inclination of his Orbit,		2	30	30
His aſcending Node in	♋	21	30	48
The Motion per Year,				36

Saturn has five Satellites or Moons attending him, and they are obſerved to be diſtant from his Center nearly, as follows,

The 1ſt	is diſtant from *Saturn*	2.1	Semidiameters of his Ring, as obſerved by Mr *Huygens*.
2d		2.69	
3d		3.75	
4th		8.7	
5th		25.35	

But by the periodic Times they are found to be 1.93, 2.47, 3.45, 8, and 23.35.

In *Engliſh* Miles,

The 1ſt, or innermoſt,	146,000	as computed by Mr *Whiſton*.
2d,	187,000	
3d,	263,000	
4th,	600,000	
5th,	1,800,000	

Their periodical Revolutions round him are nearly perform'd as follows,

		D.	H.	M.	S.
The 1ſt,	in	1	21	18	27
2d,		2	17	41	22
3d,		4	12	25	12
4th,		15	22	41	14
5th,		79	7	48	0

And their Velocities round him reſpectively

19,400	Miles per Hour.
18,500	
14,300	
9,400	
5,600	

Their greateſt Elongation from the Body of *Saturn*, as ſeen from the Earth, at a mean Diſtance, are

	Min.	Sec.
Of the 1ſt,	0	44
2d,	0	56
3d,	1	18
4th,	3	2
5th,	8	52

And the Radius of *Saturn*'s Disk,

	Deg.	Min.
To the moſt inward one is	12	52
To the next	10	7
To the third	7	7
To the fourth	3	10
And to the laſt	1	3

The Leaſt of thoſe Planets are very near as big as our Earth, and they all move in Orbits near to the Plain of *Saturn*'s Ring.

According to the Laws of Gravity,

		Days.	Hours.
The 1ſt	would fall to *Saturn*'s Surface in about	0	8
2d		0	12
3d		0	19
4th		2	20
5th		14	1

In ſome Poſitions of *Saturn*, theſe Satellites have their Eclipſes, Tranſits, and Occultations, and require the ſame Situations as thoſe of ♃ to be viſible.

Saturn's Zodiac, is about $60^{\text{deg.}}$ broad, but every Satellite is not viſible to all Parts of his Globe, nor at all times the Sun itſelf.

The various Revolutions of theſe Moons, produce to *Saturn* 5 Sorts of Months, of which his Year reſpectively conſiſts, *viz.*

Of the firſt there are	5700	in one Year.
Of the ſecond are	3932	
Of the third	2352	
Of the fourth	674	
Of the fifth	135	

Of

Of the Parallax of the Planets Orbits.

TO every ſuperior Planet, the inferior ones being circumſcrib'd within their Orbits can never come to an Oppoſition with the Sun, but will always be found in the ſame Quadrant of the Heavens with him, and can never be farther from him, than the Angle ſubtended by the Radius of their reſpective Orbits form'd by the Tangent to the Eye of the Obſerver.

This is called the Extent of the Sector of Viſion, and is always equal to the greateſt Elongation of a Planet, or the right Parallax of its Orbit.

And may always thus be found,
As any ſuperior Planet's Diſtance from the Sun,
Is to Radius, or Sine of the Quadrant;
So is the inferior Planet's Diſtance from the Sun,
To the Sine of its Elongation, or right Parallax.

Thus we find, that to an Eye at the Planet *Venus*,

The greateſt Elongation of *Mercury*,
In Aphelion is 40$^{\text{deg.}}$ 35$^{\text{min.}}$

And the leaſt Semiſector of Viſion of the ſame Planet,
In Perihelion 24$^{\text{deg.}}$ 57$^{\text{min.}}$

And to an Eye at the Earth, thoſe of

	Deg.	Min.	
Venus are	47	47	*Maximus.*
	44	55	*Minimus.*

And of

Mercury	28	22	*Max.*
	17	34	*Min.*

To an Eye at *Mars*.

	Deg.	Min.	
Thoſe of the *Earth*,	47	21	*Max.*
	36	13	*Min.*
Of *Venus*,	31	46	*Max.*
	25	34	*Min.*
And of *Mercury*,	19	44	*Max.*
	10	38	*Min.*

To an Eye at *Jupiter*,

	Maximus.			*Minimus.*	
	Deg.	Min.		Deg.	Min.
Thoſe of *Mars*,	19	39	and	14	42
Of the *Earth*,	11	51		10	23
Of *Venus*,	8	27		7	34
And of *Mercury*,	5	25		3	14

And to an Eye at *Saturn*,

	Maximus.			*Minimus.*	
	Deg.	Min.		Deg.	Min.
Thoſe of *Jupiter*	37	18	and	29	24
Mars	10	40		7	53
The *Earth*	6	30		5	36
Venus	4	39		4	5
And of *Mercury*	2	59		1	45

BOOK II.

THE HYPOTHESIS DEMONSTRATED.

SECT. I.

Of the Laws of Motion.

THE Laws by which the Planets move and are kept in their Orbits round the Sun are two, namely, the Power of Gravity, and that of the Projectile. And theſe two Virtues, by which they mutually act upon all Bodies and effect orbicular Motion, are are called the centripetal and centriſugal Forces.

The firſt, or centripetal Force, is that Principle or Virtue infus'd thro' every Particle of Matter, by which the Parts of every Body endeavour ſolid Union, and naturally tend to one common Center, and if once alone and abſolutely at Reſt, if undiſturb'd by any external Cauſe, would eternally remain in their quieſcent State.*

By

* If Reaſons were always to be expected for the affirming of ſelf-evident Truths, this alone would be ſufficient to prove Creation an Act of God. For as Reſt by the firſt Law, would have been eternal, and as no Effect can be produced without a Cauſe, the Motion of mere Matter, which could not by the ſecond Law be ſelf-acquired, muſt of neceſſity proceed from an external, pre-exiſting and independent Being.

By this Law, a Stone or any other heavy Body being thrown up in the Air, falls, or gravitates to the Earth again; and all Bodies, tho' never ſo remote endeavour to approach, and if not ſtopp'd in time would meet.

The centrifugal Force, is that Power which any Body being once poſſeſs'd of, tho' as no original Property in Matter, ever retains as a Property, if nothing be applied or interpoſe, that may diſturb its uniform progreſſive Motion.

By this Law any Body once put in Motion, will always continue to move in the ſame rectelineal Direction, and with the ſame Velocity *ad Infinitum:* For a Virtue once given, if not overpower'd, deſtroy'd, or render'd ineffectual, muſt ever remain.

This Force cannot be acquired, but muſt be given; but the true Cauſe of this continued Motion or from whence it ſprings, no human Penetration muſt ever expect to find. Hence it may be juſtly called, the active and apparent Power of God.

By this Law, all Bodies compell'd to move round any given Center, exert all their Force and Power to fly off from the circular Motion, and endeavour to effect a rectelineal one; but being incapable of this, and alſo of falling to the Center, betwixt the two is produced the various Orbits of the planetary Bodies.

The firſt of theſe, namely the attractive Quality of Matter, is more or leſs in every Body, in Proportion to the Quantity of Matter, and the ſecond or projectile Power, is always as the Quantity of Matter and the Velocity together, and theſe two Powers acting conjunctly at the ſame Time, produce the planetary Orbits thus.

FIGURE I.

If the Body C was alone and undiſturbed in the Place 'tis repreſented in, it would by the firſt ſelf-centering Principle always remain there: But if its Situation be within the Sphere of Attraction, of a much greater or more powerful Body A, it will by the ſame Law that keeps its own Parts in firm Union, endeavour to meet the Body A, and the Point of Contact will be G.

If the Body C had no natural Tendency to the Body A, or more properly, if the Body A were removed to an infinite Diſtance from that of C, ſo as to render its Virtue of no Effect at C; and if C by any external Impulſe become a moving Body along the Line CH; then C now no way adhering to A or to any other Body, in the ſame Space of Time (the Motion being continued) it would reach to H; by the ſame Law, *i. e.* of its uniform Progreſſion continued on, it will move thro' an equal Space of the ſame right-line Direction HI, and ſo on *ad Infinitum.*

But if the Body A aſſume its former State, and be allowed to exert its Power upon C, and if at the ſame Time C begins to exert its new-born Force of Levity or Freedom from A, in the Direction of CI, it will ſtill be compell'd to adhere to the more powerful Principles of A, whilſt it continues within the Sphere of A's Activity, and ſo perpetually deflect from the Direction of its rectelineal Motion to that of a Curve.

Let the Power of Gravity in C towards A for any given Space of Time, be as the Part of the Line, which joins their Centers C L; and let a projectile Force be given to C at the ſame Inſtant at right Angles to it, which in the ſame Time alone would remove the Body to H: Now both theſe Forces acting together with different Directions; in the Time the Body C under the Conduct of either, and independent of the other, would be carried reſpectively from C to H or L, by the joint Influence of both it would be conveyed to K; for K is equally diſtant from H and from L, as H and L is from C, and joining the two Forces together by the Line CK, form what the Mathematicians call an *Aſtronomical Area*, *viz.* the Triangle CKA, which is always equal to that of its ſimple Generation CHA, and ever proportional to the periodic Times.

To illuſtrate this great Problem firſt propoſed, and limited by *Kepler*; reduced to Theorem in *Lemmata*, by * *Gallileus*; and ſolv'd in all its various conſequent Effects, by Sir *Iſaac Newton*;

Let us ſuppoſe the Ball or Body C, to be thrown or projected with any determin'd Force towards H; Gravity immediately acting upon it, it will deflect from the Line CH, and deſcribe a curvelineal Arch, but meeting with Reſiſtance ſuperior to its centrifugal Power, it may fall at D; if a greater original Force be given it toward I, before it is overcome by Gravity, 'tis poſſible it may reach to E: If a ſtill greater rectelineal Force, it may arrive at F; and if greater ſtill, 'tis probable it may come to G. But if at Length a Force of Levity be given it, equal to that of Gravity, it will at laſt return to C; and may poſſibly ſtill retain ſo powerful a Propenſity for continuing its now uniform Motion, as to be able to perform a Repetition of this Orbit, and after that a third Revolution, and ſo on, with its Velocity undiminiſh'd to the End of Time.

Thus the Moon, as at BBB, perpetually renews her monthly Courſe about the Earth, and all the primary Planets, &c. their unvaried Orbits round the Sun, and where either of the above Powers are leaſt predominant, that Part of the Orbit moſt deflects from a right Line, or if otherwiſe comes neareſt to a perfect Circle; but the Excentricity of any Orbit is ever more or leſs, according to the original Direction of the Body and Quantity of the Force impreſt, and very often a circular Orbit may change its Form and become an Ellipſe from its Approach or too near Proximity to any external and powerful Body; thus the Moon's Orbit is continually changing its Species from the Oppoſition to the Quadratures of the Sun, &c.

But in all Orbits generated by the mutual Gravity of any two Bodies, if undiſturbed by a third, the Areas deſcribed are proportional to the Times. That is to ſay,

FIGURE

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* *Gallileus* found out the Laws of Gravity, and *Kepler* the Effects of it.

FIGURE II.

In the concentric Circle POHCK the Motion being always uniform about the Center ⊙, the Areas, ſuch as PO⊙ deſcribed in equal Times, in all Parts of the Circle, muſt of conſequence be equal; and alſo in the excentric Circle RQPONMD, where it is ſuppoſed not equal, but accelerated toward ⊙ and retarded from it, in the ſame Time the moving Body is paſſing from M to S, it would alſo paſs from Q to R, and the Spaces or Areas QR⊙ and N⊙M deſcribed by the Radii drawn to ⊙ in thoſe equal Times, would likewiſe be equal. The ſame is to be underſtood of the two Ellipſes, the Sun being ſuppoſed the common Focus of both; in one of which, the Spaces LK⊙ and I⊙H are equal and generated in the ſame Time; and in the other the Areas E⊙F, C⊙D and G⊙B are all equal and alſo produced in equal Time. Thus the great Comet of 1680, which in its Aphelion was ſo inactive and indolent, as ſcarce to move at all, when in its Perihelion (by the undeniable Principle of Geometry) is demonſtrated to have mov'd with a Velocity, much ſwifter than that of a Cannon Ball when firſt exploded, and almoſt equal to that of Light.

The Proof of theſe Mathematical Concluſions may be comprehended in *Fig.* III.

The Body B in an uninterrupted rectelineal Motion, would move from O to C in the ſame Time it would move from B to O; but being drawn off from its rectelineal Direction, by Virtue of the Body A immediately acting upon it, and at right Angles to CD, it will deſcribe the uniting Line or Diagonal of the Forces P B; but the Triangles BOA and PBA are upon the ſame common Baſe BA, and betwixt the ſame Parallels OQ conſequently (by *Euclid*, B. I. Prop. 38) the Areas will be abſolutely equal.

In like Manner may be prov'd, that the double Quantity of ſimple Motion CAB, is alſo equal to the double Quantity, or Area, of compound Motion RBA, and that likewiſe the ſecond Space PS, deſcribed in a like Interval of Time, form an equal Area both with RAP and PAQ.

In a third Particle of Time, the ſame Body would move from S to K; then on to M, and ſo to N, ever deſcribing Areas proportional to the generating Times. But here, the Force of Gravity decreaſing, as the Square of the Diſtance increaſes, in this Part of the Orbit the Motion is retarded, and the revolving Body inſtantaneouſly moves ſlower.

As alſo the Body at F in the Ellipſis FEGH, tho' there the projectile Force *ce*, &c. ſeems to conſpire with the curvelineal Direction: But towards G, the moving Force is every Moment accelerated, the projectile Power *gw*, and that of Gravity *wy*, both conſpiring with the acquir'd Velocity and the natural Direction of the Curve, as is evident from the great Obliquity of the rhomboidical Spaces *iyxo*, *ox*YZ, &c.

At the Abſis E, which is called the perihelion Point of all the ſolar Planets, the Body moves faſteſt of all; and at the other Abſis I, the aphelion Point, the ſloweſt, Gravity, *b h*, there being not only the weakeſt, but alſo the centrifugal Force *d h* the moſt avers'd.

Of apparent Motion.

BESIDES the real progreſſive Motion of the ſeveral Planets round the Sun from Weſt to Eaſt, in reſpect of one another they ſometimes appear to ſtand ſtill, and at other Times ſeem to move contrary, as from Eaſt to Weſt, and in effect contradict their own proper Motions.

Thus the Inhabitants upon the Earth, like the Crew of a Ship at Sea, may think all the Objects they ſee are flying from them, while their own real Motion in a contrary Direction, is all the while effecting the *Deceptio Viſus*, and is the only true Cauſe of it.

To ſolve this Phænomena, with regard to the Planets, (See *Fig.* III.)

Let A repreſent an inferior Planet, and B a ſuperior One, or ſuppoſe A the Earth and B *Jupiter* or *Saturn*, &c. Now the Motion of A being much ſwifter than that of B, while B is moving to H, I, or K, A will have got reſpectively to E, F, or G: Conſequently B now ſuppoſed to be removed, which from the Point A appeared amongſt the fix'd Stars at *x*, when the Eye is in E, F or G will be ſeen ſucceſſively at *w v* and *t*. Here B will apparently move, as from *Aries* to *Taurus*, and in this Caſe be direct, or as the Aſtronomers term it, moving in Conſequentia; as will alſo A at the ſame Time appear to do from an Eye at B.

But if B were in any other Part of its Orbit, in reſpect of A, or which is all one, if A were removed to M; whilſt B is in paſſing from I to S or K, A would advance from N to O or M, and here the two Bodies would ſeem amongſt the Stars to ſtand ſtill; in this Caſe, a Planet not appearing to move at all, is ſaid to be ſtationary.

Laſtly, if B was poſited at Q while A was at N, by that Time B was got to P, A would have come to M; in this Poſition, B from A, and conſequently A from B, would appear to go backwards, *i. e.* from ♉ unto ♈, having firſt from N appeared at *r*, and then ſoon after to O and M in *s* and *t*.

This is called Retrogradation, or the Motion of the Planets in *Antecedentria*, they thus appearing to move from Eaſt to Weſt.

Thus *Jupiter* to an Eye at *Mars* in O or M, at R and P will be found to be retrograde, as from *o* to *p*, but direct at *z*: *Venus* to *Jupiter* or *Saturn* at L, will appear likewiſe to be retrograde; and moſt ſenſibly ſo in her Tranſit from *k* to *a* and *b*, but to *Mars* in the ſame Part of her Orbit from V, W and T, ſhe will appear firſt direct near *h* and *i*, then ſtationary about *k*, and afterwards retrograde towards *a* and *b*, as appears by the Poſition of the Lines of Direction to *l*, *m*, *n*, *&c.*[*]

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[*] By the Help of theſe Motions, *Milton* conveys his Idea to us of the Dance of Angels round the Throne of God. (*Book* V. L. 620.)

> Myſtical Dance, which yonder ſtarry Sphere
> Of Planets and of fix'd, in all her Wheels,
> Reſembles neareſt, Mazes intricate,
> Eccentric, intervolv'd, yet regular
> Then moſt, when moſt irregular they ſeem,
> And in their Motions Harmony divine,
> So ſmooths her charming Tones, that God's own Ear
> Liſtens delighted.——

The Poles of theſe alternate Motions are ſuch as **D** and **C**, change their Situation every Revolution.

The Times when any of the Planets become ſtationary to their Directions or Retrogradation, to an Eye at the Earth, with their Poſitions and Continuations, may be ſeen in the following Table.

A Table of the mean Stations and geocentric Motions of the Planets.

Viz. Of	*Saturn.*		*Jupiter.*		*Mars.*		*Venus.*		*Mercury.*	
	Commutations.									
	deg.	min.	deg.	min.	deg.	min.	deg.		deg.	
Angle at the Sun, when ſtationary to direct or retrograde	66	0	53	30	22	30	15	0	32	0
	Elongations.									
Angle at the Earth, when commencing retrograde or direct,	108	0	116	0	135	0	28	0	22	0
Days retrograde,	132 138 143		393 400 406		61 71 82		39 42 44		20 22 24	
Degrees retrograde,	6 6 6	35 47 59	9 9 10	48 56 5	10 14 19	10 57 45	18		8 12 16	26 18 11
Days direct, betwixt one Retrogradation and another,	374 378 382		116 120 125		$2^{y.}$ $33^{d.}$ — —56 — —80		$1^{y.}$ 212 —218 —224		108 117 126	
Moſt retrograde,	☉ in ♏ ♄ in ♋		☉ in ♏ ♃ in ♋		☉ in ♑ ♂ in ♏		☉ in ♊		♍	
Leaſt retrograde,	☉ in ♈ ♄ in ♐		☉ in ♊ ♃ in ♒		☉ in ♋ ♂ in ♓		♀ in ♑		♊	

N. B. The mean Conjunction of *Saturn* and *Jupiter*, are made every 19 Years 312 Days, and about $8^{\text{ſigns}}$ $2^{\text{deg.}}$ $47^{\text{min.}}$ aſunder. (*See* Philoſophical Tranſactions, *Numb.* 149, *by Mr* Flamſtead).

SECT.

SECT. II.

Of Light and Heat.

LIGHT is propagated through the etherial Medium as a real Subſtance, and has all the Properties of a material Body, but the Minuteneſs of its Particles are ſuch, that one Grain of any ſolid Subſtance productive of it, being reduced to a Flame, is capable of filling a ſpherical Space of a League Radius, and that ſucceſſively repeated for ſeveral Moments together. This is the neareſt Approximation that can poſſibly be made in the human Mind, of the infinite Diviſibility of Subſtances, towards conceiving, in the Imagination, an adequate Idea of the primitive Particles of Matter.

The Propagation of Light is not inſtantaneous, but is prov'd to be progreſſive, and not caus'd by the Agitation of any etherial Medium; its Velocity is found to be different thro' different Mediums, and has been obſerved to come from the Sun to the Earth in about 7 or 8 Minutes; this is determined by the Eclipſes of *Jupiter*'s Satellites, compar'd near the Conjunction and Oppoſition of the Sun; and from theſe and many ſuch like Obſervations, we conclude that the mean Velocity of Light,

Is nearly	650,000,000	Miles per Hour.
	10,800,000	per Min.
And	180,000	per Second of Time.

But to treat of the various Reflections, Refractions, and Incurvations of Light, belongs properly to Opticks, and I may preſume will not be expected here, ſo ſhall content myſelf at preſent with ſpeaking of its relative Degrees of Heat.

Light and Heat to all equal Bodies, or the ſame Surfaces, as proceeding from any radiant Point, is reciprocally proportional to the Square of the Diſtance from that Point, (*i. e.* as the Denſity of the Rays) and as all Parts of the Sun may be look'd upon as ſuch, in reſpect of the Planets, this will evidently appear, from the equal Rays falling upon the Bodies A, B and C; their unequal Diſtances from the Luminary being as 2, 3 and 6, and their Light reſpectively, as 81, 36, and 9; *i. e.* 36 to 4, 36 to 9, and 9 to 4.

Thus Light and Heat being ſuppoſed at the Earth as	1,
To *Venus* it will be as	2,
To *Mercury* as	6.

And to Bodies within one Diameter of the Earth from the Sun's Surface, not leſs than as 100,000,000.

To *Mars* in the ſame Proportion it will be

Nearly, as $\frac{4}{10}$; to *Jupiter*, as $\frac{1}{27}$; and to *Saturn*, as $\frac{1}{90}$.

Hence it may be made appear, that the Comet of 1680, which in its Perihelion approached within leſs than a ſixth Part of the Sun's Diameter from him; nearly, as 6 to 1000 in reſpect of our Earth, muſt have acquir'd an Heat, which to that of our Summer's Sun, would be as 1,000,000 to 36, or as 28,000 to 1; and as the Heat of the drieſt Earth in Summer, is from Experience, found to be to that of the hotteſt boiling Water, as 1 to 4, and as the Heat of boiling Water, is ſtrongly ſuſpected to be 3 or 4 times leſs than that of red hot Iron, we may conclude that the Heat which ſuch dry Earth in the Comet might have conceived from the Sun-beams in that Point, was very near 2000 times greater than that of red hot Iron.

By the ſame Way of Reaſoning we may alſo infer, that the ſame Comet, when in its Aphelion, paſs'd thro' a Portion of Light 20,000 times leſs warm than that we receive from our Summer Sun; conſequently as our Air 4 or 5 times leſs enlighten'd, is frequently in a freezing State, this Comet at that vaſt

Diſtance

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Diſtance from the Sun, muſt have indured a Degree of Cold, relatively 4000 times greater than that of freezing Ice.*

Sir *Iſaac Newton* ſeems to have been of Opinion, that the above Comet muſt retain its Heat for an exceeding long Time, from imagining that a Globe of red hot Iron equal to our Earth, expos'd to the immediate Contact of the open ambient Air, would be 50,000 Years in cooling. But had he once reflected on the intenſe Regions of Cold, this Body was to paſs thro', he would ſoon have reduced it to its mean or temporate State.

Tis hardly poſſible that theſe Globes, from the great Extreams of Cold and Heat, they are ſubject to paſs through, (tho' undoubtedly durable) ſhould be inhabited Bodies, or that they ſhould finally drop into the Sun; which Sir *Iſaac Newton* intimates they muſt at laſt do; for tho' we are almoſt poſitive, he has an attractive Power, yet we have many Reaſons to believe that he has alſo a repelling one near his Surface; and if he has Power to throw vaſt Maſſes of Matter, from or out of his own Body into his Atmoſphere, ſuch as appear like Spots upon his Disk, which very few doubt of, no other Body can be ſuppoſed to have Power to approach him.

The only Cauſe of new Stars they cannot be. Vid. *periodical Appearances.* But how all this may really be, whether they are ordain'd to feed the other Parts of Nature's Works with freſh Supplies of ſolid or of fluid Matter, or whether they are barren Bodies fram'd on purpoſe for a perpetual Change in Creation's great Variety; the Cauſe of Conflagrations, Deluges, or total Cataſtrophies, or be they Worlds themſelves not quite † deſtroy'd, or new

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* The Nature of Comets was not unknown in *Milton*'s Time, and it is very probable *his Deſcription of the damn'd, or State of the Fallen Angels* might be taken from them.

Thither by harpy-footed Furies hail'd, 600
At *certain Revolutions*, all the Damn'd
Are brought, and feel by turns the bitter Change
Of fierce *Extreams*, Extreams by change more fierce;
From Beds of raging *Fire*, to ſtarve in *Ice*
Their ſoft etherial Warmth, and their to pine,
Immovable, infix'd and frozen round;
Periods of Time, thence hurried back to Fire.

Milton, *Book* II. *L.* 600.

† Quer. whether the ſolar Spots may not be broken Parts of Comets, tore to pieces by the exceſſive Heat of the Sun in their neareſt Proximity.

creating from their old Remains, will never be known, till ſome of the human Race have been Eye Witneſſes of ſuch a Diſſolution, either by the Loſs of ſome one of the known Planets we now ſee, or have upon the Earth experienced ſuch a Change themſelves.

This we may be ſure of, it is as poſſible for the infinite Power to be perpetually creating, and perpetually deſtroying Worlds, as by Death and new Life he is ever ending and beginning the human Generations, *&c.* And as this is evident to our Senſes, and obvious in our preſent Being, what may we not expect and hope for in a future State.

But to return. The Proportion of Light and Heat to all Parts of the ſame Globe, is very far from being equal in Degree, tho' equal in Duration, *i. e.* all the different Regions of the Earth, enjoy the Sun's Light one half of the Year, and are deprived of it the other; yet the Proportion of Heat is vaſtly different.

Thus to the Globe at E (*Tab.* II.) five Beams are requir'd to fill the Spaces F G and G H, where the Sun is nearly vertical; when at the ſame Time one performs the like Office, covering an equal Space D E and I K, the Sun being then near the Horizon.

This is the Reaſon, why the Summer is to us in the North Parts of the World ſo much warmer than the Winter; the Mornings and Evenings ſo much colder than Mid-day; and is the Cauſe from whence proceeds the diſtinction of the Zones. * Two being originally judg'd temperate, and the other three intemperate Extreams.

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* And as five Zones th' etherial Regions bind;
Five correſpondent are to Earth aſſign'd;
The Sun with Rays, directly darting down,
Fires all below, and fries the middle Zone;
The two beneath the diſtant Poles complain,
Of endleſs Winter and perpetual Rain;
Betwixt th' Extreams two happier Climates hold
A Temper, that partakes of hot and cold.

Dryden's Ovid.

The Rays of Light, falling upon the Earth, coming from ſo great a Diſtance as the Sun, may be look'd upon as parallel; ſuch are repreſented by the Lines L E and N I, *&c.* and in this Caſe, the immediate Warmth, proceeding from the Sun, will be nearly reſpectively as the Difference of the natural Sines of his Diſtance or Declination from the Zenith.

How much the Heat in Summer, Winter and Spring, differ in the Middle of the temperate Zone, appears by the oblique Rays falling upon the Line R X.

Of Refraction. Tab. III.

ALL Rays of Light, coming from any luminous Body, in paſſing thro' different Mediums, are variouſly reflected and turn'd out of their original Direction, always deviating from the Point or Line of Direction towards a Perpendicular in the new Medium.

Thus the Ray R arriving at A, will appear, as if it came in the Direction of the Line S, and the Path deſcribed by any Particle of Light near the Horizon, will the moſt deviate from a right Line, as the Ray T G Q O A will firſt in the Medium ♂ deſcribe the Line F G; then in the Medium ♀, the Line G H; afterwards in the Medium ☿, Q O, and laſtly in the Medium ☾, ☉ A.

But as the Atmoſphere is in every Point of Elevation, of a different Degree of Denſity, decreaſing in a certain Ratio, nearly as the Square of the Diſtance from the Earth's Surface increaſes, this Path will be a regular Curve of the parabolick Kind.

The Atmoſphere, like the Earth itſelf, is of a ſpheroidical Figure, but ſomething more oblate than the Earth; it is much lower under the Poles than in the Equator, and is ever varying its Denſity and Elevation, with the Sun's Advance and Decline.

Its greateſt Height has never been known to be above 60 Miles, and in this Degree of Expanſion or Dilation, the uppermoſt Clouds in the Zenith of one

Place, as at W, will appear to another 1000 Miles diſtant in the Horizon; as at X or at Y; but that ſame Cloud ſeen 300 Miles from the Zenith Station, will appear about 45$^{deg.}$ high; as Y from Z, *&c.*

In this Scheme, (*Tab.* III.) B repreſents the Horizon Point to an Obſerver at A; C the Place where the Sun produces the *Aurora* to A; and D his Depreſſion below the Horizon at the End of the Crepuſculum to the ſame Station; and where the Sun ſinks no lower than this, there can be no real dark Night.

Of the Viciſſitude of Seaſons.

AS the Viciſſitude of Day and Night is occaſioned by the Earth's Rotation round her Axis; ſo the Diverſity of Seaſons is in like Manner caus'd by the various Poſition of the Poles, in reſpect of Light and Shade, ariſing from the annual Revolution round the Sun. For as the Plain of the Earth's Equator never changes its Inclination to that of the Ecliptic; it follows, that the Poles of the World muſt always be directed to the ſame fix'd Star, and conſequently the equatorial Plain in all Parts of the Earth's Orbit, muſt ever lie parallel to its primitive Poſition, and the diurnal Axis muſt always move parallel as to itſelf. Hence the two Poles will alternately be enlighten'd by the Sun, and interchangeably immerſe or emerge, to or from the obſcure Hemiſphere.

All this evidently appears by *Tab.* IIII. being a perſpective View of the Earth in her Orbit; the Eye being ſuppoſed at an infinite Diſtance in the Plain of the Equator.

The ſeveral Projections are Sections of the Sphere, repreſenting the Earth at the Sun's Ingreſs to every Sign.

The primitive Circles repreſent in every Place the equinoctial Colure, and the parallel Lines in the polar Directions the ſolſtitial one: The Points as P P P are the North Ecliptic Poles, or Poles of the Sun's apparent Motion thro' the Ecliptic; the Poles of the World are thoſe, as at A and B the

North ones, and C and D the South ones; the Circles as V I ♑ W; repreſent an Arch of the Ecliptic, and ÆQ; ÆQ &c. the Equator; E F is the Tropic of *Capricorn* and G that of *Cancer*.

The Circles meeting at the Poles, are all horary Circles, of 15$^{\text{deg.}}$ each, and the oblique Circles croſſing one another at the ecliptical Poles, are Circles of the Sun's Longitude, of 30$^{\text{deg.}}$ each anſwering to the 12 Signs.

Now tis plain, the Earth being at H, and the Sun in *Capricorn*; the North Pole of the World will be in Darkneſs, and the South will be in Light. But when the Earth is removed to K, the South Pole will then be in the Shadow, and the North one enlighten'd; at M and N, the ſolar Horizon will paſs thro' both Poles, and conſequently the Nights and Days will there be nearly equal to all Parts of the World, the Sun then riſing and ſetting every where near the Hours of 6 and 6.

The Progreſs of Light, and the gradual Increaſe and Decreaſe of Day and Night, may be very eaſily trac'd in any given Latitude, to all Parts of the World, in the adjacent Schemes, which are each reſpectively, Projections of the Sphere, to every aforementioned Poſition of the Earth thro' the Seaſons. They repreſent the horary Meridians and Parallels of Latitude in Plano, concentric to the Poles; the double ſhaded Part repreſent Night; the ſingle ſhaded Part, the Dawn or Twilight; and the unſhaded Part Day.

By which, if proper Regard be had to the Hemiſphere of the Place, the Light falling upon oppoſite Parts of the Globe, being ever alternately equal, and ſucceſſively Suppliments to each other; the Time of Sun riſe, Sun ſet, Length of the Day, Night, or Twilight; at any Time of the Year, and to any Part of the World will be nearly ſhown.

Thus *London* at its ſhorteſt Day, will firſt appear to the Sun at *e*, and enter the Cone of Night at *d*; the Sun will riſe a little after 8 and ſet as much before 4. The Day will break about 6, whilſt *London* is at *c*, and the Length of the Crepuſculum will be about 2 Hours.

But at Midſummer the Sun will riſe when *London* ſhews itſelf at *b*, a little before 4, and ſet a little after 8 when *London* comes to *a*, and there will be no Night all, by reaſon *London* will not here reach the perfect Shadow.

SECT. III.

Of the Equation of Time.

TIME is the Meaſure of Motion, eſpecially that of our Earth, from whence our Idea of Time proceeds; and if this were equable and uniform, there would be no ſuch Thing as Equation; that is, if the Earth's anual Orbit was a perfect Circle concentric to the Sun, and if the Earth moved an equal Part or Portion of that Circle every Day, and if at the ſame Time the Axis of her daily Motion were to be always perpendicular to the Plain of her Orbit, Time would ever be equal.

But as the Motion of the Earth, is both unequal in its Orbit, and oblique upon its Axis, Time as entirely depending upon it, muſt alſo be unequal and ſubject to an Equation.

The Cauſes from whence the Equation may proceed are many, but the chief, or moſt ſenſible, ſuch as have already come under our Obſervation are only two. The firſt and greateſt is this.

The Sun's apparent mean diurnal Motion in the Ecliptic, is, taking one Day with another about $59^{min.}$ $8^{2ds.}$ but this equal Quantity in the Earth's Orbit, from the Obliquity of the Ecliptic, produces an unequal Quantity in the Equinoctial, and renders the Sun's Appulſe to the Meridian unfixt to any certain Time. And from this daily Interval of Motion ariſing from the Earth's

Advance in her annual Orbit, being various, not only from the Difference of the Sun's daily right Aſcenſion, but alſo from the unequal Diſtance of the Sun in Longitude, and right Aſcenſion from the neareſt equinoctial Point, ſprings the firſt Equation thus. See *Fig.* V.

Let E M Q C repreſent one Quadrant of the Equator, and C H I S an equal Portion of the Ecliptic: Let A be the North Pole of the World; P that of the Ecliptic, and H the Sun's Place, ſuppos'd in his Paſſage from *Aries* to *Cancer*, and near the Beginning of *Taurus*.

Now it is plain as the Earth revolves upon its Axis in this Poſition of the Sun, the Point R is the true right Aſcenſion of Time, as coming to the Meridian with the Sun: But if the Sun inſtead of moving in the Ecliptic, had in the ſame Time deſcribed an equal Arch of the Equator; which muſt have been the Caſe, if the Earth's diurnal Axis had been perpendicular to the Plain of its Orbit; the Point Q which here comes ſomething later to the Meridian than R, and repreſents the Mean or equal Time, would then have been the apparent, and alſo the true Time, but the Difference betwixt the two, is the Angle QAR, and here repreſents the Equation, whoſe Nature and Quantity is ſhown upon the Dial at X, and there you may perceive, that Clocks will be before the Sun. At C the Ecliptic and Equator unite, and at S the Sun's Longitude and right Aſcenſion co-inſide; conſequently in theſe two Points, this Kind of Equation muſt vaniſh; at I, the Sun's Ingreſs to *Gemini*, the Equation will be equal to that of H, and betwixt the two, *i. e.* in about $15^{\text{deg.}}$ of *Taurus*, it will be the greateſt of all, and then equal to $9^{\text{min.}}\ 55^{\text{2ds.}}$

Thus, if one entire Revolution of the Sun were repreſented, you will find that in the Spring Signs, or firſt Quadrant of the Ecliptic, Clocks and Watches will be ſlower than the Sun, and this equated Quantity, muſt be ſubſtracted from the apparent Time to produce the Equal.

In the ſecond Quarter, or in the Summer Signs, Clocks will be faſter than the Sun, and the Equation muſt be added to produce equal Time; in the Autumn Signs it will be of the ſame Nature with the Spring Signs; and in the Winter the ſame as in the Summer.

The ſecond Cauſe of Equation, properly proceeds from an Equation of the firſt Equation, which hitherto we have conſider'd, as the Effect of an equal Motion in an oblique Direction. But now we muſt look upon it to be unequal, and the Reaſon why it is ſo, will appear from what follows.

From the Theory of the Earth's primary Motion, we prove that the Sun's Progreſs thro' the Southern Signs, is made much ſooner than thro' the Northern ones, as thus.

Anno Dom. 1732, being *Biſſextile,*

	D.	H.	M.
The Sun entered *Aries* on *March* the	8	17	54
And came to the Beginning of *Libra*, on *September* the	11	11	38
And in the common Year, 1733,			
Approach'd to *Aries* in *March* the	8	23	43
And advanc'd to *Libra* in *September* the	11	17	35
Hence the Length of the Summer Seaſon will be	186	14	44
And the Duration of Winter	178	12	5
And the Difference of what we call the Summer and Winter half Years	8	5	39

Hence 'tis plain, the Earth's Motion muſt be alternately faſter and ſlower in her elliptical Orbit, according to her Diſtance from the Sun, and will occaſion a ſecond Inequality of Time, which will be this.

Let CDE repreſent half the Earth's elliptical Orbit; let A be the Center, to which the mean or middle Motion of the Earth is referr'd, and P the other Focus, repreſenting the Sun. Here E D will be the Line of the Abſides, and reſpectively E and D the Aphelion and Perihelion Points.

Now if the Earth be at G it is eaſy to conceive from the Figure and parallel Poſition of the Line *a* A, the true Motion of the Earth will go before and move faſter than the Mean; In this Caſe Clocks will be too ſlow for the Sun: At C this Equation will be the greateſt, to which, from the Abſis D, the Quantity increaſes; and from which, to the Abſis E, the Quantity decreaſes; but on either Side, as at Y and K, it is very inconſiderable. In the firſt ſix Signs of the Anomalia, this Equation muſt be added to the apparent Times to gain the equal, but in the latter ſix it muſt be ſubſtracted; its greateſt Quantity is about $7^{\text{min.}}$ $44^{\text{2ds.}}$ and how it affects Time is ſhewn at *b c* and *e*.

Q *A*

A Table of the Equation of Time,

Compoſed ſor common Uſe; ſhewing how many Minutes the mean or equal Time, is faſter or ſlower than the apparent, or Sun's Time, every Day in the Year.

Jan.	*Feb.*	*Mar*	*Apr.*	*May*	*June*	D.	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*
min.	min.	min.	min.	min.	min.		min.	min.	min.	min.	min.	min.
9	15	10	1	4	1	1	5	5	4	13	16	6
9	15	10	1	4	1	2	5	4	4	14	15	5
10	15	10	0	4	0	3	5	4	5	14	15	5
10	15	9	0	4	0	4	5	4	5	14	15	4
10	15	9	0	4	0	5	5	4	5	14	15	4
11	15	9	0	4	0	6	5	4	6	15	15	3
11	14	8	1	4	0	7	6	3	6	15	14	3
11	14	8	1	4	1	8	6	3	6	15	14	2
12	14	8	1	4	1	9	6	3	7	15	14	2
12	14	7	1	4	1	10	6	3	7	15	14	1
12	14	7	2	4	1	11	6	2	7	15	13	1
12	14	7	2	4	1	12	6	2	8	16	13	0
13	14	7	2	4	2	13	6	2	8	16	13	0
13	14	6	2	4	2	14	6	2	8	16	13	1
13	13	6	2	4	2	15	6	1	9	16	12	1
13	13	6	3	3	2	16	6	1	9	16	12	2
14	13	5	3	3	3	17	6	1	9	16	12	2
14	13	5	3	3	3	18	6	1	10	16	11	3
14	13	5	3	3	3	19	6	0	10	16	11	3
14	12	4	3	3	3	20	6	0	10	16	11	4
14	12	4	3	3	3	21	6	0	11	16	10	4
14	12	4	3	3	4	22	6	1	11	16	10	5
14	12	3	3	2	4	23	6	1	11	16	9	5
15	11	3	4	2	4	24	6	1	12	16	9	6
15	11	3	4	2	4	25	5	2	12	16	8	6
15	11	3	4	2	4	26	5	2	12	16	8	6
15	11	2	4	2	4	27	5	2	12	16	8	7
15	10	2	4	2	5	28	5	3	13	16	7	7
15	10	2	4	1	5	29	5	3	13	16	7	8
15		1	4	1	5	30	5	3	13	16	6	8
15		1		1		31	5	4		16		9
Clocks too faſt.			Too faſt. Clocks too ſlow.	Clocks too ſlow.	Too ſlow. Clocks too faſt.		Clocks too faſt.	Clocks too faſt. Clocks too ſlow.		Clocks too ſlow.		Clocks too ſlow. Clocks too faſt.

The Reaſon why the Seconds are not added in this Table, muſt be obvious to every *Aſtronomer*, ſince no Table of this Kind, depending upon the *Sun's Place*, can be near true to Seconds, for more than eon Year in four, and that but to one time of the Day.

But in order to be able to keep a juſt Regulation of Time, and know how to diſtinguiſh at any time the mean or equal, from the apparent Time; a Movement ſhould be made, whoſe Pendulum ſhould vibrate true Seconds of equal Time; and that all the Oſcillations may be as near equal to one another as poſſible, it is neceſſary that the Librations ſhould be made betwixt and againſt two Cycloidical Curve Surfaces, as B Z D and B E, whoſe Semi-chord, or Subtenſe, is as B D. And the Diſtance from the Point of Suſpenſion B to the Center of Motion W, ſhould be to different Parts of the World, as in the following Table.

Latitudes.	Length of Pendulums.		Meaſure of a Degree in the Meridian.
Deg.	Feet.	Lines.	Toiſes.
0	3	7.468	56637
5	3	.482	642
10	3	.526	659
15	3	.597	687
20	3	.692	724
25	3	.812	769
30	3	.948	823
35	3	8.099	882
40	3	.261	945
41	3	.294	958
42	3	.327	971
43	3	.361	984
44	3	.394	997
45	3	.428	57010
46	3	.461	022
47	3	.494	035
48	3	.528	048
49	3	.561	061
50	3	.594	074
55	3	.756	137
60	3	907	196
65	3	9 044	250
70	3	.162	295
75	3	.258	332
80	3	.329	360
85	3	.372	377
90	3	.387	382

Their Differences ariſe from the Figure of the Earth. See Sir *Iſaac Newton*'s *Principia*.

SECT.

SECT. IV.

Of the Phænomena *of the Planets.*

ALL Dark Bodies expoſed to the direct Light of any luminous one, will ever be enlighten'd on the oppoſing Side, and if both Bodies are ſpherical, the extream Verge of the reflecting Disk, will be a perfect Circle, and if the two Bodies be equal in Magnitude, this Circle will divide the opaque Globe into two equal Hemiſpheres, one dark the other light.

But if the radiant and reflecting Globes be of different Magnitudes, the Line of this Biſection, or rather of the Separation of Light and Darkneſs, will form its Surface into two unequal Parts or Segments, of which, if the Light proceeded from one only radiant Point, the dark Part would be the greateſt; but if from any luminous Body greater than the dark one, the irradiated Part will be greateſt, and the Difference betwixt the two apparent Hemiſpheres will always be, firſt, in Proportion to the Difference of the Bodies themſelves; and ſecondly ſubject to vary with the apparent Diameter of the radiant Disk, as the Diſtance aſunder increaſes or decreaſes.

FIGURE VI.

Thus the Moon at N is enlighten'd by the Sun, and reflects to us the ſolar Beams in the Direction of L O from the Surface LMI, and tho' her Globe ſcarcely bears any Proportion to that of the Sun in Bulk, yet being ſo very far remote from him, the ſhadowy Part is almoſt equal to the lucid one. Conſequently the light Side being always towards the Sun, and turn'd from us as at Q, the dark Part muſt very near if not quite obſcure it, and her Globe, to the Earth at Z, in that Poſition be inviſible; but as the dark Part of the Moon is always ſomething leſs than the refulgent Part, there will even be in this Poſition, a bright ſilver Verge round the Moon, like an illuminated Atmoſphere.

But as this can never be ſeen, but in the exact *Syzygia* with the Sun, we muſt never expect to be Eye-witneſſes of it, but in very total Eclipſes of the Sun, ſuch as of the Year 1715, at which Time ſuch a Phænomena did appear, and was by many attributed to the Rays of Light in the Moon's Atmoſphere. But notwithſtanding this might have occaſioned ſome ſmall Reſemblance of this lucid Ring, yet we have ſtronger Reaſons to induce us to believe ſhe has no ſuch Thing as an Atmoſphere.

At Y the Moon ſtill keeping her light Side *q*, *t*, *r*, towards the Sun, part of her dark Side *q s* will be turn'd away from the Earth; in this Caſe, a ſimilar Part of her Light *t r* will be ſeen, and ſhe will appear horn'd; and increaſing with her back towards the Weſt, at X one half will appear enlighten'd, but as being only one Quarter of her Globe, it is called the firſt Quarter of the Moon; at W ſhe will appear gibboſe; the Part *a c* being only wanting now to make her imperfect Disk *e d b* complete to *e*.

At U the dark Side is quite removed ſrom an Eye at the Earth, and the ſame Side appears to the Earth, as is ſeen from the Sun; in this Poſition the Moon is always full-faced with Light, and continues ſo in abſolute *Plenilunam* for ſome time, at leaſt an Hour, but the exact mean Duration of the Moon's full-face is $1^{h.}$ $3^{m.}$ $5^{2ds.}$ the light Hemiſphere being more than half her Globe; at V ſhe ſhews the ſame Face as at W, but is here decreaſing on the oppoſite Side of her Body; *h g* is equal to *a e* and ſimilar to *f i*.

At T ſhe is again biſected as at X, and this is called the laſt Quarter; at R ſhe ſhews the ſame Quantity of Light as at Y, cut off by the Angle of Appearance *m z n q s*, being here equal to *c i*, and alſo equal to *m p*, her Back as here declining is always to the Eaſt.

How to project the Quantity of Light at any Time, and repreſent the Moon's general Phaſes. See the Figure at M, where B E ſhews the Limits of Light, as received from the Sun; A B the Portion cut off from the Earth by the Line A C; A B D H the Field of Light, and G A and E D the firſt and laſt extream Rays reflected to the Earth.

Now as a Circle view'd obliquely, has always the Appearance of an Ellipſe, the Moon's Light will always be form'd by joining the two Curves in oppoſite Points, according to the Obliquity of the Plain, dividing the Hemiſphere of Light and Shade to that of the Disk, as HDI to HAI, or HCI, in I and H. DC, *&c.* being always as the Sine Complement of the Moon's Diſtance from the Sun.

As the Moon is perpetually changing and producing new Phaſes to the Earth, ſo in like Manner all the inferior Planets perform the ſame Diverſity of Appearance to the ſuperior Planets.

Thus *Mercury* and *Venus* are ever changing their Faces to the Earth, the Earth to *Mars*, *&c.*

FIGURE VII.

But the Planets to one another, do not only change their Phaſes, but alſo vary very ſenſibly their apparent Magnitudes, for *Venus* appears much the largeſt to the Earth, when ſhe affords it the leaſt Light, as is plain from her apparent Disk at O, P and Q; and *Mercury* the ſame. *Since therefore it appears, that we are deprived of by much the greateſt Share of their reſpective Light, the moſt uſeful Thing to us, it is a ſtrong Argument that they were not made for our Uſe alone, at leaſt in this Reſpect, and may very poſſibly be inhabited Worlds themſelves.*

Mercury at A, to the Earth at B, appears horn'd, and at the ſame Time to *Mars* at H, he would appear as in the Change; at N he would appear gibboſe; and at M to E with a full Face. *Venus* at B to the Earth at E would alſo appear gibboſe; and at F, to *Mars* in I, ſhe would ſeem biſected, but at the ſame Time to the Earth gibboſe; at D *Venus* would appear like a half Moon to the Earth at E, but from *Mercury* at M gibboſe. The ſuperior Planets never appear to the inferior ones horn'd or biſected; but the moſt neighbouring Ones, ſometimes, when near their *Quadratures*, appear gibboſe, as *Mars* at C, will ſhow to the Earth at E, and the Earth in C to *Mercury* and *Venus* at D and M.

The Quantity of Light at G cut off from the Eye at E, is *n s*, but to the Eye at C it is *o y*, *z* being common to both, and *j x*, *o w* their Supplements. At A, *g h* form all the Light to E, *i g* being the viſible Hemiſphere, and *k* the obſcure one.

At B, *c d b* is all the apparent Light to E, *a e c* being dark, and its ſimilar Part inviſible; at C, *m o s u* cut off the Light to D, and *q o p* what is ſeen from M.

Of Eclipſes.

AS the Globes of the Earth and Moon are both opaque Bodies, which borrow all their Light from the Sun, and as their Shadows are nothing but the Loſs or Privation of Light, in the Space oppoſite to the Sun, it follows that where either interpoſes, the Sun's Rays will be intercepted, and the other if within reach of the Shadow, muſt in ſome Part be obſcured. Hence it is eaſy to conceive, that a ſolar Eclipſe is cauſed by the Interpoſition of the Moon, between the Sun and the Earth, and a Lunar one by that of the Earth, betwixt the Sun and Moon.

Thus it is manifeſt their can be no Eclipſe of the Sun, but when the Moon is in the Change, for at no other time her Shadow can be caſt upon the Earth; and no Eclipſe of the Moon can happen but at the Full; the Moon then only being in the Shadow of the Earth's Way. And ſince there is a new and a full Moon every Month, we muſt now explain why there is not an Eclipſe at theſe Times every Month alſo. The Reaſon is this, If the Moon's Orbit lay in the Plain of the Ecliptic, there would be a total Eclipſe of the Moon at every Full, and a central Eclipſe of the Sun at every Change. But the Orbits of the Earth and Moon being placed obliquely, and not in one and the ſame Plain paſſing thro' the Sun, interſect each other in two Points call'd Nodes, where the Moon's Orbit is found to make an Angle with the Ecliptic as mentioned in her Theory of about 5 Degrees.

Therefore the Moon may be in ſuch a Poſition in her Orbit, as to paſs the ecliptic Oppoſition or Conjunction, either too high or too low to fall in the Earth's Shadow, or to be able to throw her Shadow upon the Earth.

Hence it is poſſible, every new and full Moon may not be eclipſed, and it is farther plain, no Eclipſe can happen unleſs ſhe is near one of her Nodes, conſequently the Quantity of Obſcuration will depend upon her Diſtance from the Node, and both Kinds may be either total, partial, or central.

A total Eclipſe of the Sun, is when all the Sun's Body is obſcured by the Moon, as at B; and a total Eclipſe of the Moon, is when all the Moon's Body is enveloped in the Earth's Shadow; as at BCD and L, of which there are two Kinds, *viz.* Total with Continuance, as through ABCDE, and KLMN; and total without Continuance in the Direction of HBG.

A partial Eclipſe of the Sun or Moon; is when the Whole cannot be obſcur'd, ſuch as I, F and M, in the Poſitions HK, HE, and GH; and F and D of AG and EC.

A central Eclipſe of the Moon, is when the Moon paſſes thro' the Center of the Earth's Shadow, as at C, and a central Eclipſe of the Sun, is when the Centers of the Sun and Moon are perfectly conjoin'd in abſolute *Syzygia* as at B, of which there are two Kinds, *viz.* firſt, central and total with or without Continuance; and ſecondly, central, not total, called *Annular*, at which Time all the Moon's Body appears upon the Sun's Disk, and encompaſs'd with a Ring of Light, as at R to the Earth at L, and in this Caſe the Moon's Shadow does not reach the Earth.

But the Moon being leſs than the Earth, and the Sun greater, her Shadow can never cover the whole Globe, only a Part of it, and total Darkneſs is but to thoſe Inhabitants, on whom the Shadow falls. The circumjacent Places will be illuſtrated with ſome of the Sun Beams, call'd the *Penumbra*, or a lucid partial Shadow, as E O, which will have different Degrees of Illumination, according to the Diſtance from the Center or Surface of the real one. Without this *Penumbra* all the Sun's Disk will be ſeen at the ſame Time, and no Eclipſe perceived at all.

FIGURE VIII.

Let S repreſent the Sun; E the Earth; I the Moon, and C her Shadow; draw the Line *a* KN and *b u* D, and then KDN will be the penumbral Cone. Now it is plain, while the Moon is in the Line SIE, there will be a total Eclipſe to the Earth at L; but without the Points D and N there will be no Eclipſe at all. But if the Moon were either at F or H, (which here may repreſent the Beginning and End of an Eclipſe in I) the Sun might be totally eclipſed to N or D, but in both which Poſitions to the Earth at L, the Sun would be free from Obſcuration.

Hence the Radius of the Penumbra, is always equal to the Sum of the Semidiameters of the Sun and Moon, and is repreſented at T. And if no Part of this Penumbra falls upon the Earth's apparent Disk in the Moon's Orbit, as R, which is found by ſubſtracting the Sun's horizontal Parallax ZWS, from the Moon's horizontal Parallax *gw*R, there can be no Eclipſe in that Part of the Moon's Orbit.

But if the Sum of the Semidiameters of the Disk and Penumbra, be greater than the Moon's true Latitude; then an Eclipſe to ſome Part of the World muſt unavoidably happen. And if the Moon's Latitude be leſs than the Semidiameter of the Disk, the Eclipſe will be central, and may be total.

In like Manner from the Moon's Diameter, Latitude and Radius of the Earth's Shadow in the Moon's Orbit, (which is found from ſubſtracting the Semi-Angle of the Cone *k* X *i* out of the Moon's horizontal Parallax *k* XM) we determine when an Eclipſe of the Moon will happen.

For if at any Time the Sum of the Semidiameters of the Moon and Shadow exceeds the Moon's true Latitude, as at M, that full Moon will be eclipſed. And if their Difference be more than the ſaid Latitude, it will be total.

But the Moon, altho' deprived of the direct ſolar Beams, is not abſolutely hid from us at the ſame Time, becauſe the Rays of Light paſſing thro' our Atmoſphere are refracted, and thrown obliquely into the real Shadow, as from *w* to ☾, and thereby faintly illuminates the whole Cone.

Hence it is that the Moon's Body remains viſible to us, tho' in a total Eclipſe.

This Illuſtration may be in ſome meaſure increaſed, if not occaſion'd by a Reflection from the Earth's real Surface; ſince in this Poſition there will always be a Verge of Light round the Earth's Globe, viſible to the Moon.

The Limits of ſolar Eclipſes is in the mean Quantity, $18^{\text{deg.}}\ 10^{\text{min.}}\ 41^{\text{2ds.}}$ from the Nodes.

And of lunar Eclipſes $11^{\text{deg.}}\ 53^{\text{min.}}\ 3^{\text{2ds.}}$ from the ſaid Nodes.

Hence it appears, there may be many more ſolar Eclipſes to the World than lunar Ones.

But ſolar Eclipſes are not univerſal and lunar ones are; therefore there may be more lunar Eclipſes to any particular Place than ſolar ones *.

How to conſtrue or calculate the Duration and Quantity of Eclipſes to any given Place, is ſhewn in my *Synopſis*, at the End of the Uſe of the Globes, printed for Mr *Senex*.

Of

		Y.	D.	H.	M.	2ds.	
* Mr *Whiſton* makes the mean Period of Eclipſes to be from a common Year - - - - - - - -		18	10	7	43	30	
And from a Biſſextile - - - - - - - - - -		18	11	7	43	30	
Hence a Return of the Solar Eclipſe of	1724, in *May*	0	11	6	36	0	P. M.
By adding the Period	18 Years	0	11	7	43	30	
May be expected in	1742, *May*	0	22	15	19	30	
And the Lunar Eclipſe of	1732, *Nov.*	0	20	9	44	10	
By adding the Period	18 Years	0	11	7	43	30	
Will produce an Eclipſe	*Anno* 1750, *Dec.*	0	1	17	27	40	

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Of Tranſits and Occultations.

FIGURE IX.

A TRANSIT is the apparent Paſſage of an inferior Planet over the Sun's, or any ſuperior Planet's Disk.

Let A repreſent the Earth, B the Sun, and FL and MG reſpectively, the Orbits of *Mercury* and *Venus*; then to an Obſerver upon the Earth at H, I will be a Tranſit of *Mercury*, and K a like viſible Conjunction of *Venus* in her Paſſage over the Sun; and ſuch will always happen in every Conjunction, when the Planet's Latitude is leſs then the Sun's Semidiameter.

The Poſition of the Line of Direction over the Disk, with reſpect to the Horizon, depends upon the Planet's Altitude and Diſtance from the *Nonageſimal* Degree, and may be either as RTXV, WTS, or ZXS, *&c.*

An Occultation, is the diſappearing of any Planet or Star when conjoin'd with the Moon, in a Space oppoſite to the Eye, ſuch as at E and C; the Moon paſſing betwixt us and it, as at D ſeems to cover it; by which Means it becomes inviſible to us, and remains hid from our Sight all the Time the Moon is paſſing thro' the Spaces E or C.

N and P repreſent each an Immerſion, and Q and O the Emerſions. The various Poſitions of theſe Appulſes is ſhewn by the Immerſions *f*, *b*, *h*, and *a*, and their reſpective Emerſions *e*, *d*, *c*, *&c.*

Occultations happen to almoſt all the Stars in the Zodiac, that are within the Limits of the Moon's Orbit, in every Revolution of the Moon's Node, and always at ſuch a Time, when their Latitude from the Orbit is leſs than the Moon's Semidiameter. Which how to calculate, as alſo Tranſits. *See* the Doctrine of Eclipſes abovementioned.

SECT.

SECT. V.

Theory of the Tides.

THE Ocean being equally preſſed by the Force of Gravity towards the Earth's Center, would always remain of the ſame Depth, and neither ebb nor flow, if the Earth were undiſturbed by any external Power. But as the Sun and Moon are prov'd to have like Principles of Gravitation towards their Center: and as the Earth is found to be within the Sphere of their Activity, which decreaſes in attractive Force, as the Square of the Diſtance from their Centers increaſes; the Cauſe of the Flux and Re-flux of the Sea will be very evident from what follows.

FIGURE X.

Sir *Iſaac Newton* has demonſtrated from the Theory of Gravity, and the Hypotheſis of the Sun and Moon, *&c.* That the Moon's Force to the Force of Gravity in raiſing the Sea,

Is as 1 to 2871400. And that of the Sun,
As 1 to 12868200.

Hence the lunar Power is to the ſolar Power nearly, as 4.4815 to 1, which in effect upon the open Sea, will produce an Elevation of Water, equal to 8 Feet $7\frac{5}{22}$ Inches by the Moon, and by the Sun 1 Foot $11\frac{1}{30}$ Inches, together $10\frac{1}{2}$ Feet; in Perigeon $12\frac{1}{2}$ Feet, and in Apogeon $8\frac{1}{2}$ Feet.

This is in a great Meaſure agreeable to Obſervation; for in the great *Pacific* and *Ethiopic* Oceans, the Water is found to riſe 6, 9, 12, and ſometimes 15 Feet; but in Channels, Bays and over Shoals, the Elevation is ſometimes augmented to 30, 40, and 50 Feet.

Let Figure X repreſent the Earth, every where covered with deep Water; and ABC various Poſitions of the Moon. While the Moon is at A, I is the

Place where ſhe appears in the Zenith, and *k* where ſhe is in the Nadir; now it is plain the Water above I being nearer, is more attracted by the Moon than the Center of the Earth is, and the Center of the Earth is more drawn towards the Moon, than the Water about *k* is; whence the Water about I, having a greater Tendency towards the Moon than the Earth has, and the Water about *k* a leſs, by as much as the Exceſs of Gravitation in I above that in U, and of U, above that in *k*, it follows, that the Sea, which if equally preſs'd on all Sides, would be ſpherical, muſt form itſelf into a ſpheroidical or oval Figure; ſuch as S E *m c* F X G *e* D, whoſe longeſt Axis or Diameter will always be towards that Point where the Moon is vertical and the ſhorteſt in the lunar Horizon; and as the Moon is ever changing her Poſition, both by the Earth's diurnal Motion and her own, the Water ſhifts along with her, as from O to P, and from H to N and K, *&c.* and occaſions the Floods and Ebbs twice in every $24^{h.}$ $48^{m.}$

The ſpring Tides, following the new and full Moons, are occaſioned by the united Force of the Sun and Moon conſpiring together in Oppoſition and Conjunction; and the neap Tides after the Quarters, are produced from the Difference of the two Forces; the Sun depreſſing the Water where the Moon raiſes it, as from D S E to D V E; and raiſing the Water where the Moon depreſſes it, as from O to R.

The equinoctial ſpring Tides, *i. e.* in *March* and *September*, being the higheſt, and their Neaps the Loweſt, proceed from the great Agitation of the Waters, when the Spheriod revolves about a greater Circle of the Earth, than when it turns about a Leſſer. Which is plain from this, if the Moon was always fix'd above the Pole; the Spheroid of Water would always remain in the ſame Poſition; making perpetual High-water under the Pole, and Low-water every where under the Equinoctial. Conſequently the nearer the Moon approaches to the Poles, the leſs will be the Agitation of the Sea, and the greateſt of all will be where the Moon is over the Equator, but here, and in all other Places, the Elevation of Water may be augmented or diminiſh'd, according to the Aſpect of the Sun and Moon from the *Syzygia* to the *Quadrature.*

Hence the ſubſequent neap Tides to thoſe of the equinoctial ſpring Tides, are always the leaſt, and the ſubſequent neap Tides to the tropic ſpring Tides, always the moſt vigorous; the Former being produced by the ſolſtitial Moon, and equinoctial Sun, and the Latter by the ſolſtitial Sun and the equinoctial Moon. Thus it happens, that the Difference betwixt the ſpring and neap Tides, in *June* and *December*, are conſiderably leſs than thoſe of *March* and *September*.

But by reaſon the Sun is ſomething nearer the Earth in Winter than in Summer; the very higheſt ſpring Tides never happen preciſely upon the Day of the Equinox, but generally a little before and after it, *i. e. February* and *October*.

Thus far we have conſidered the Phenomena of the Tides as univerſal, without any Relation to particular Caſes, and the different Situation of Places; what follows from the various Parallels of Latitude, may be underſtood by the Figure.

Let *n g* be the Poles of the World, and *h f* the Equator; let *z e* and YC be two Parallels of Latitude, equally diſtant from the Equator; let HI be the two Points where the Moon is vertical or in the Nadir, and let RQ be the great Circle where the Moon is in the Horizon.

It is plain that a Spheroid deſcribed upon HI, and RQ will repreſent the Figure of the Ocean, and it is evident, that *x e*, *h* D, *d y*, *b c*, *f* F and *a z* will be the reſpective Height of the Sea to the Places *x*, *h*, *d*, and *a*, *f*, *b* at the Time of high Water; and ſince by the Rotation of the Earth in 12 Hours Time, the Point D will be transferr'd to F, and Y to C, &c. Y *d* will be the Height of the Water, when the Moon is preſent, and *b c* the Height of the Water when the Moon is abſent (*et vice verſa*) which is here alternately greater and leſs; and in the oppoſite Parallel the contrary.

The greateſt of the two high Waters in each diurnal Revolution, is that where the Moon approaches neareſt to the Zenith or Nadir of the Place;

this is the Reaſon why the Moon in the Northern Signs, to the North Parts of the World, makes the deepeſt Tides when above the Earth, and in the Southern Signs, below it; the Effect being always the greateſt when the Moon is moſt elevated or depreſs'd, above or below the Horizon.

But the Motions of the Sea, here mentioned, are ſubject to an Alteration in Poſition, from a Libration or projectile Force, impreſs'd upon the fluid Figure, whereby, tho' the Action of the Sun and Moon ſhould ceaſe, the Flux and Re-flux of the Sea, for ſome Time, would continue. This Conſervation of the impreſs'd Motion diminiſhes the Differences that otherwiſe would be between any two conſequent Tides, and is the Reaſon why the higheſt ſpring Tides are not preciſely on the new and full Moons, nor the Neaps on the Quarters, but generally the third Tides after them, and ſometimes later.

All theſe Things would proceed regular, if the Earth were every where covered with deep Water. But interpoſing Continents, Straits, and the Shallowneſs of the Sea in many Places, produce ſome few Exceptions from theſe general Rules, *viz.*

That in the open Ocean the Time of high Water is never at the Moon's Appulſe to the Meridian, but always ſome Hours after it; as upon all the Weſt Coaſt of *Europe*, *Africa* and *America*, where the South Weſt Moon makes full Sea; and hence Lakes, and ſuch as the *Caſpian*, *Mediterranean*, and the *Black Seas*, the *Straits*, and the *Baltick* have no ſenſible Tides; for Lakes having no Communication with the main Ocean, can neither increaſe or diminiſh their Waters, whereby to riſe or fall; and Seas of immenſe Extent that do communicate with the Ocean, by ſuch narrow Inlets, cannot in a few Hours time receive or empty Water enough to ſwell or ſink their Surfaces any thing ſenſibly. *See this Doctrine farther explain'd and accounted for, in Sir* Iſaac Newton's Principia, *and in the* Philoſophical Tranſactions, N° 162.

SECT. VI.

Of Comets.

BESIDES the Planets, which all move round the Sun from Weſt to Eaſt near the Plain of the Ecliptic; there are other ſurpriſing Bodies in the Syſtem call'd Comets, whoſe Motions are perform'd in very different Plains, and in all manner of Directions, both direct and retrograde.

Theſe Bodies have appeared in all Ages, but being much more ſwift in their apparent Motions than the Planets, generally remain viſible but a very ſhort Space of Time.

The ancient Philoſophers took them for Meteors,† but the Moderns finding them to have no diurnal Parallax, have concluded they muſt be far above the Moon; and now by many Obſervations compared together, and Returns of ſome, they are at laſt found to be of the ſame Nature with the Planets, and ſubject to the ſame Laws of Motion, but in vaſt excentric Orbits, yet in every Part deſcribing Areas proportional to the Times.

Sir *Iſaac Newton* has demonſtrated,
That the periodic Time of any Comet,
Is to the periodic Time of any Planet,
In a ſeſquiplicate Proportion of their principal Axis.

That is, if the Axis of a Comet's Orbit, were to the Axis of a Planet's Orbit, as 9 to 1, the periodic Time of the Comet would be to the periodic Time of the Planet, as $9\surd 9$ to 1, or as 27 to 1. Hence a Comet moving in an Orbit 9 times the Axis of *Jupiter*, will be 324 Years in performing one Revolution round its Orbit.

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† *Ariſtotle* was of Opinion that the Comets were nothing but ſublunary Vapours, or airy Meteors.

And the Velocity of a Comet thus moving in an Ellipſe, is to the Velocity of a Planet moving in a Circle at the ſame mean Diſtance from the Sun, nearly in a ſubduplicate Proportion of double the Diſtance of the Planet, to the Diſtance of the Comets, or as $\sqrt{2}$ to 1.

The Orbs and Bodies of the Comets appear thro' Teleſcopes, to be ſurrounded with very denſe Atmoſpheres, eſpecially in thoſe returning from the Neighbourhood of the Sun; at which Time they generally emit vaſt Tails, ſometimes like fiery Beams, and frequently much brighter than the Milky Way. Theſe Tails are always turn'd from the Sun, and often extend to 30, 60 and 90 Degrees in Length.

There are many Opinions concerning the Subſtance and Matter of theſe Tails; but the Generality of Aſtronomers in the preſent Age agree, that they are produced and form'd of a thin Vapour ariſing from the Head or Nucleus, and reflecting the Sun's Light.

The Heads of all the late Comets, ſince the Year 1500, have never exceeded $8^{min.}$ or $12^{min.}$ and the Nucleus, or Star, is generally $\frac{1}{10}$ or $\frac{1}{15}$ of the whole Diameter; near the Sun the Nucleus are the Leaſt, being there the moſt obſcur'd by Smoak, but the Light of the Head generally increaſes from the Earth towards the Sun, and decreaſes from the Sun to the Earth.

Flamſtead in the Year 1682, obſerved the Comet's Head, to be $2^{min.}$ in Diameter, but the Nucleus he found to be no more than $12^{2ds.}$ and the Head of the Comet in the Year 1665 was above $6^{min.}$ and the Nucleus leſs than *Jupiter*.

The apparent Motions of Comets in general are very unequal, inſomuch, that *Hevelius* in *July*, 1683, obſerved a Comet to move $40^{min.}$ and $45^{min.}$ per Day, which in *September* following, he found moved $5^{deg.}$ per Day.

Sir *Iſaac Newton* having demonſtrated, that Comets might move in ſuch vaſt eccentric Ellipſes, that near the Sun; Parabolas (of a more eaſy Solution) might be made Uſe of inſtead of them: The late Dr *Edward Halley*, from a Collection of ſuch Obſervations as could be depended upon, fram'd the following Table, being the Reſult of a prodigious deal of Calculations.

The Theories of all the COMETS *that have been duly obſerv'd.*

Anno D.	Temp. Equat. Periheli.				Perihelion.				Perih. Diſt. a Sole.	Nodi aſcend.				Orbitæ Inclin.			Motio.
	M.	D.	H.	M.	S	D.	M.	S.	100000	S.	D.	M.	S.	D.	M.	S.	
1337	June	2	6	25	♉	7	59	0	40666	♊	24	21	0	32	11	0	Retrog.
1472	Feb.	28	22	23	♉	5	33	30	54273	♑	11	46	20	5	20	0	Retrog.
1531	Aug.	24	20	18 ½	♒	1	39	0	56700	♉	19	25	0	17	56	0	Retrog.
1532	Oct.	19	22	12	♋	21	7	0	50910	♊	20	27	0	32	36	0	Direct.
1556	April	21	20	3	♑	8	50	0	66390	♍	25	42	0	32	6	3	Direct.
1577	Oct.	26	18	45	♌	9	22	0	18342	♈	25	52	0	74	32	45	Retrog.
1580	Nov.	28	15	0	♋	19	5	50	59628	♈	18	57	20	64	40	0	Direct.
1585	Sept.	27	19	20	♈	8	51	0	109358	♉	7	42	30	6	4	0	Direct.
1590	Jan.	29	3	45	♏	6	54	0	57661	♍	15	30	49	29	40	40	Retrog.
1596	July	31	19	55	♏	18	16	0	51293	♒	12	12	30	55	12	0	Retrog.
1607	Oct.	16	3	50	♒	2	16	0	58680	♉	20	21	0	17	2	0	Retrog.
1618	Oct.	29	12	23	♈	2	14	0	37975	♊	16	1	0	37	34	0	Direct.
1652	Nov.	2	15	40	♈	28	18	40	84750	♊	28	10	0	79	28	0	Direct.
1661	Jan.	16	23	41	♋	25	58	40	44851	♊	22	30	30	32	35	50	Direct.
1664	Nov.	24	11	52	♌	10	41	25	102575 ½	♊	21	14	0	21	18	30	Retrog.
1665	April	14	5	15 ½	♊	11	54	30	10649	♏	18	2	0	76	5	0	Retrog.
1672	Feb.	20	8	37	♉	16	59	30	69739	♑	27	30	30	83	22	10	Direct.
1677	April	26	0	37 ½	♌	17	37	5	28059	♏	26	49	10	79	3	15	Retrog.
1680	Dec.	8	0	6	♐	22	39	30	00612 ½	♑	2	2	0	60	56	0	Direct.
1682	Sept.	4	7	39	♒	2	52	45	58328	♉	21	16	30	17	56	0	Retrog.
1683	July	3	2	50	♊	25	29	30	56020	♍	23	23	0	83	11	0	Retrog.
1684	May	29	10	16	♏	28	52	0	96015	♐	28	15	0	65	48	40	Direct.
1686	Sept.	6	14	33	♊	17	0	30	32500	♓	20	34	40	31	21	40	Direct.
1698	Oct.	8	16	57	♑	0	51	15	69129	♐	27	44	15	11	46	0	Retrog.
1723	Sept.	16	16	10	♉	12	15	20	99865	♈	14	16	0	49	59	0	Retrog.
1737	Jan.	19	8	20	♒	25	55	0	22282	♏	16	22	0	18	20	45	Direct.
* 1742	Jan.	27	21	50	♏	7	33	28	76890	♎	5	47	22	68	14	0	Retrog.

Theſe three laſt I have added; one * of which I obſerv'd and conſtructed myſelf, the other two are as computed by Mr. *Bradley*, Reg. Profeſſ.

Dr *Halley* was of Opinion, that the Comet of 1682, was the ſame that appeared in the Year 1607, and before in the Year 1531, concluding its Period to be $75\frac{1}{2}$ Years. That the Comet of 1661, might be the ſame that appear'd 1532, and its Period 129 Years; and that the great Comet of 1680 muſt have been the ſame with that of 1106, which likewiſe appear'd at *Julius Cæſar*'s Death, and alſo in the Conſulate of *Lampadius* and *Oreſtes*, conſequently its Period will be about 575 Years; and hence the tranſverſe Diameters of theſe three Comet's Orbits, will be found reſpectively, $\sqrt[3]{75\times75}$, $\sqrt[3]{129\times129}$ and $\sqrt[3]{575\times575}$ times greater than that of the Orbis Magnus.

Hence the greateſt Diſtance from the Sun.

Of the	1ſt	will be about	2,900,000,000	Miles.
Of the	2d		4,012,000,000	
And of the	3d		11,200,000,000	

Their mean Diſtances.

1,458,000,000
2,025,000,000 Miles.
6,600,000,000

And their mean Velocities per Hour.

13,000
9,000 Miles.
6,000

Of the Stars.

THE Stars are looked upon by all modern Aſtronomers, to be no other than great Globes of Fire like the Sun, promiſcuouſly diſtributed through the Mundane Space, and may very poſſibly be the Centers of other Syſtems of Planets like ours, ſince we have no Reaſon that can contradict it, and many that may induce us to believe it.

Their various apparent Magnitudes are intirely the Effect of an unequal Diſtance, as will manifeſtly appear from the Scheme of their Diſpoſition, where the ſame Stars D E F G H, altho' their Globes be repreſented equal, appear reſpectively of different Magnitudes, as is evident from the different Points of View A B and C in the equal Arches of Viſion R S, T V and O Q. EFGH, as ſeen from D, appear like Part of the *Pleiades*, a bright Knot of Stars and D K from C, as the double Star of *Caſtor*, &c.

The ingenious Mr *Huygens*, from the Analogy of apparent Light, having contracted the Sun's Image, by Means of a ſmall Hole at the End of his Teleſcope, to the Appearance of *Syrius*, $=4^{\text{3ds.}}$ found, that the Sun's Diſtance to that of *Syrius* was nearly, as 1 to 27664; hence the Diſtance of *Syrius* in round Numbers from us, will be at leaſt 2,213,120,000,000 Miles, and conſequently, according to the Velocity of Light, if *Syrius* was to be totally extinct before the laſt Rays could reach the Earth, the Star itſelf would have been put out 142 Days.

Its hardly poſſible for a thinking Being to view this vaſt Creation of glorious Bodies, whoſe aſtoniſhing Extent no human Eye can ever diſcover, or the Mind comprehend, without being ſtruck with an awful Dread and Admiration of the great Creator's Wiſdom and amazing Power; and altho' the Exiſtence of himſelf, and manner of acting from his own divine Nature can never come under our our Obſervation, or into the finite Sphere of our weak Cognoſcence; yet his Ubiquity and Omniſcience, have ever been acknowledged to the higheſt Degree of Adoration, and his State always allowed to be perpetually the ſame; the only one primitive and independent, the ſole ſupream God, original Maker and Diſpoſer of all created Things; of infinite and eternal Majeſty, and of univerſal Dominion. In the old Heathen Worſhip, he is called *Jupiter* or *Jove*, and *Virgil* finely expreſſes their Notions of him as in the following Lines.

——————The Heav'n and Earth's compacted Frame,
The flowing Waters and the ſtarry Flame;
And both the radiant Lights, one common Soul
Inſpires and ſeeds and animates the Whole:

This active Mind infus'd thro' all the Space,
Unites and mingles with the mighty Maſs.
Hence Birds of Air and Monſters of the Main,
And Men and Beaſts the Breath of Life obtain.

DRYDEN'S VIRGIL.

An Explanation of the different Stiles in the Account of Time.

THE *Julian* Account of Time, commonly call'd the old Stile, takes its Name from *Julius Cæſar*, and was firſt ſettled * 45 Years before *Chriſt*.

In this Account of Time, the Year is ſuppoſed to conſiſt of $365^{\text{days.}}$ and $6^{\text{hours.}}$ but the odd Hours not being taken Notice of annually, every four Years amount to a Day; and hence every fourth Year by the Addition of this one Day more than in the common Year of 365, becomes a Biſſextile or Leap Year of $366^{\text{days.}}$ Now the true ſolar Year ſucceſſively conſiſting of only $365^{\text{d.}}\ 5^{\text{h.}}\ 49^{\text{min.}}\ 16^{\text{2ds.}}$ here is an over-reckoning of $10^{\text{min.}}\ 44^{\text{2ds.}}$ yearly, and this annual Variation in every 134 Years, producing one Day to be rejected is the Reaſon why the vernal Equinox, or the Sun's Ingreſs to *Aries* is now on the Tenth of *March*, which in *Julius Cæſar*'s Time was on the 24th, having changed as follows,

Sun in *Aries.*

		March.	Years before Chriſt.
In the Time of	*Euctomon*, on the	25	432
	Hipparchus	24	146
At the Birth of	*Chriſt*	23	
			Anno Dom.
Obſerved by	*Ptolomy*	22	140
	Thebu Ben Chora	17	831
	Alfraganus	16	
	Arzachel	15	1090
And in the Year 1316,		13	

X The

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* *Britain* being then a *Roman* Province received this Account, and has kept it ever ſince.

THE new Stile or *Gregorian* Account of Time takes its Name from *Pope Gregory* the XIIIth, who finding the *Julian* Account to be erroneous, reſolved upon a Reformation of it, and begun it in the Year 1582.

The Pope finding the vernal Equinox at the Time of the Council of *Nice*, to have been on the 21ſt of *March* look'd no farther back into paſt Time, and reſolved upon fixing it there for the future. To which End he order'd 10 Days of the preſent Year 1582 to be omitted, which was accordingly done, by calling the 5th of *October* the 15th, by this Means the Sun's following Ingreſs into Aries, fell on the 21ſt of *March*, which muſt have otherwiſe been on the 11th.

And to prevent ſuch like Errors for the future, he ordered 3 Days in every 400 Years to be reduced thus,

The 29th of *February*, (being the Day added in the *Julian* Account, to make Leap Year) at the End of three Centuries ſucceſſively was to be omitted, and at the End of the fourth retained.

Thus before the 29th of *February* 1700, the Difference betwixt the two Stiles was but 10 Days, and ſince, now is 11; and in the 18 Century will 12, &c.

Thus far I have thought proper to acquaint the Reader with ſuch Particulars in Aſtronomy, as are moſt generally inquir'd after by thoſe who are not profeſs'd Mathematicians; and theſe I take to be the moſt uſeful and entertaining; but thoſe who are deſirous of peruſing this Science farther, may find all the Improvements that have been made in this Study for many Ages, ingeniouſly ſum'd up, explain'd and demonſtrated in the learned Works of our indefatigable Countrymen *Flamſtead*, *Newton*, *Gregory* and *Halley*, in which they may compleat their Knowledge of all that has, or poſſibly may be done this Way.

FINIS.

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